Safe Storage Guidelines for Industrial Hemp (*Cannabis sativa*) Seeds

by

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A thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

In partial fulfilment of the degree of

MASTER OF SCIENCE

Department of Biosystems Engineering

University of Manitoba

Winnipeg

DEDICATED TO

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ABSTRACT

Canada produced 33,750 tonnes of hemp seed over 2013-2015 on approximately 36,500 hectares in the prairie provinces. The Canadian grain industry lacks a specific guideline for safe storage of hemp (*Cannabis sativa*) seeds used by farmers, industry people and throughout the world especially in Canada where it grows well. A popular variety of hemp seed known as FINOLA® - was obtained from a farm in Southern Manitoba for this study. Four independent factors were considered as follows: dockage percentages, relative humidities, temperatures, and storage periods. To develop a safe storage guideline, the hemp seed with different dockage percentages (0%, 5%, and 15%) in different relative humidities maintained by salt solutions (KNO_3, NaCl, $NaNO_2$, $Mg(NO_3)_2$) were stored at different temperatures (20, 25, 30, and 35℃) for 26 weeks. The indices of spoilage in hemp seed were seed germination, FAV (free fatty acid value), visible and invisible mold, seed plate (bacteria) count, and internal green and yellow seed count.

Germination of the hemp seed was significantly different at different percentages of dockages (0, 5, and 15%) as dockage may have held some unbound water that degraded the seed quality. But dockage percentages did not significantly influence equilibrium moisture content, FAV, visible and invisible mold, seed plate (bacteria) count, and internal green and yellow seed count. Hemp seed with 15% dockage had faster germination loss. Hemp seed with lower RH and temperatures had the lowest FAV, mold, seed plate count, and internal green and yellow seed count. Based on the 20% initial germination loss, hemp seed could be safely stored at ≤25℃ and ≤70%RH, which would be at ≤10% equilibrium moisture content, for more than 26 wk.

Keywords: hemp seed, relative humidity, temperature, moisture content, visible mold, FAV, germination, internal green and yellow seed count, storage guidelines.

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to Dr. Fuji Jian for his guidance, constant encouragement, and immense support throughout the period of my study. His company and fatherly treatment will be remembered forever.

I am also grateful to Drs. Paul Fields, Noel D.G White (Agriculture and Agri-Food Canada), Drs. Digvir S. Jayas, and Mashiur Rahman (Department of Biosystems Engineering) for their valuable suggestions and for serving on my advisory committee.

I thank the Natural Sciences and Engineering Research Council (NSERC) of Canada and the Graduate Enhancement of Tri-council Stipends (GETS), University of Manitoba for providing financial support for the project. Also, I thank Hemp Oil Canada who funded a portion of this project.

Thanks are due to Mr. Colin J. Demianyk (Agriculture and Agri-Food Canada) for his technical support and suggestions during the experimental work.

Finally, I am the most grateful to my parents for their support during the whole program of study and wish to thank my son Azraf Bin Abdullah Rehan and my beloved wife Azra Sultana for their moral support and being my strength in all situations. It is an impossible task to include everyone who assisted in the preparation of this thesis. Countless friends and associates have made their contribution, a fact that is acknowledged with sincere thanks.

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1 INTRODUCTION

Variety “FINOLA” is the most popular cultivar of 20 industrial hemp varieties. After the harvest, hemp seed should be dried to the moisture content level at which there is no longer available unbound water which is a great cause for the growth of undesirable micro-organisms (Kreyger, 1972; Sonawane, 1979; Suriyong et al., 2015). Compared with the storage of cereals, the risk of deterioration in hemp seed is higher because of the high oil content of the hemp seed (Karunakaran, 1999; Nithya et al., 2011). When seeds are infested with fungi, oil can be oxidized or hydrolyzed and that accelerates the rancidity process. To have good quality in oil content and profiles in hemp seed during long term storage period, reduction of germination, activities of microflora, and infestation of insects and mites should be avoided (Brooker et al., 1992; García et al., 1997; Wilson, 1999). The most important factors influencing the quality of stored oilseeds are temperature, moisture content and storage time and any of these factors under unsafe storage conditions might result in the spoilage of the hemp seed. To store grain and oilseeds under safe storage condition, guidelines are developed for different crops such as rye (Sathya et al., 2008), canola (Sathya et al., 2009), durum wheat (Nithya et al., 2011) and pinto beans (Rani et al., 2013). This guideline can provide the recommendations for safe storage in cereal grains and oilseeds at the recommended temperature, moisture content, and storage times. The grain industry lacks a specific guideline for safe storage of hemp seed in Canada where hemp grows well. The objectives of this study were to determine the safe storage condition of hemp seed under different combinations of temperatures, relative humidity, and dockage percentages, and to develop the safe storage guidelines as well.

LITERATURE REVIEW

1.1 Production of hemp seed in Canada

As hemp and marijuana come from same species (*Cannabis sativa*), tetra hydro cannabinol (THC) levels in industrial hemp must be below 0.3% (*Canadian Hemp Nature's wonder fibre*, 1998). More than 0.3% is not considered as industrial hemp but rather considered as marijuana that usually contains 5-10% THC. There is a resin gland in the buds and flowers of female cannabis plant which is solely liable for the high level of THC (Difference between Industrial Hemp and Cannabis, 2017). Industrial hemp never has buds that contain THC. In addition, industrial hemp carries a chemical called cannabidiol (CBD) that has negative effects on THC and no psychoactive effect occurs when consumed (Difference between Industrial Hemp and Cannabis, 2017). Industrial hemp has been used as a source of fiber as well as oilseed globally for centuries (Johnson, 2017a; Mooleki et al., 2006; Taheri-Garavand et al., 2012). This century, many things have already happened regarding legalizing the processing, possession, and cultivation of hemp especially in North America. In 1930, hemp seed was only used as a drying oil. During WWII, North America brought back hemp cultivation in exchange of other durable natural fibers (Callaway, 2004). Later, with regularity of St. Paul by Health Canada, hemp has been legally cultivated since 1998 in Canada (Fig. 1). In 2004, production was low due to prevailing law from the U.S Drug Enforcement Act (DEA). Until 2010, production rate was increased as farmers focused on increasingly positive economics of growing other crops (Johnson, 2017b).

There is a statistical report by Health Canada in 2016 that mentioned details on how many licensed hectares were given to cultivars in different provinces for the cultivation of industrial hemp. The common cultivated variety is FINOLA that covered over 8,000 hectares across Canada. Other varieties came up in descending order are X-59, Picolo, CFX-2, Katani, CRS-1, Grandi, and Canda. In 2016, two provinces were dominating cultivating the most industrial hemp – one was Alberta with Finola, X-59, Picolo, and Katani were mostly grown; the other was Manitoba with CFX-2, CRS-1, and Grandi, (Statistics, Reports and Fact Sheets on Hemp, 2016). The yield of hemp seed can be more than 2,000 kg of seed per hectare.

FINOLA was developed first in Finland and is now cultivated in Australia, Canada, England and France due to having great tolerance to frost at all stages (Ranalli & Venturi, 2004). The oil content of hemp seed (Table 1) is about 35.5% and is the highest percentages of oil carried by FINOLA variety than the other components such as protein, carbohydrates, digestible fiber, and non-digestible fiber (Callaway, 2004).

Table 1 Nutritional content (%) of variety FINOLA (Callaway, 2004)

Elements	% in whole seed
Oil	35.5
Carbohydrates	27.6
Protein	24.8
Non-digestible fiber	22.2
Moisture	6.5
Ash	5.6
Digestible fiber	5.4

A plant grown in colder weather such as Canada, is likely to produce more highly unsaturated fat than in warmer weather (Canvin, 1965). Studies on different oil seeds indicated that hemp seed is the second most oil seed that has 85% polyunsaturated fatty acids (PUFA) that is likely to minimize human blood pressure. Alpha-linoleic acid (omega-3) and gamma-linoleic acid (omega-6) - two of the most important components that the human body cannot produce internally - are found in hemp seed that also contains 2% stearidonic acid (omega-3s) which is never found in other oilseeds such as soybean (García et al., 1997; Priestley & Leopold, 1983; Stewart & Bewley, 1980; Warner et al., 1989); rapeseed (Stefansson, 1966); and sunflower (Crapiste et al., 1999).

Hemp seed have 15% saturated fatty acid (SFA), which is lower than olive or rapeseed oil, even lower than sunflower or soybean. SFA raises blood cholesterol level as well as increases the chance of heart disease in humans. As evening primrose oil is used for pre-menstrual syndrome (PMS) or mostly for skin disease, hemp seed could not only be used for body care products but also for meal to provide omega-3 and omega-6 which have a set of disease-fighting characteristics in terms of maintaining hormonal function within the human body (*Canadian Hemp Nature's wonder fibre*, 1998).

1.2 Dockage and foreign materials

Grading system in the grain industry was necessitated by the presence of foreign seeds of different species in the grain samples (Durnin, 1983). These foreign materials might be present due to improper cleaning. The more dockage in bulk seeds, the more likely molds will grow (Hartman, 2011; Nair, 1997). One study (Durnin, 1983) showed that the range of dockage percentages in bulk canola seeds are between 4 -6%. The levels in bulk hemp seed have not been yet studied. In many oilseeds, dockage consists mainly of cereal grain, broken seeds, weed seeds, and soil particles

(Hartman, 2011). The main components of dockage in hemp seed were chaff - consisting of seed coverings and small pieces of stem or leaves; others were pieces of branches, dust, dirt, trash, immature seeds.

1.3 Variables affecting grain quality during storage

Grain storage involves many variables that are physical, chemical, and biological. The important variables involved in grain deterioration are moisture content, equilibrium relative humidity (ERH), and temperature (Copeland & Macdonald, 2001; Desai, 1997; Hartman, 2011; Justice & Bass, 1978; Šimić et al., 2007; Singh et al.,2017). How these variables affect the quality of grain is described below and which were determined by seed germination, visible or invisible mold, the fat acidity value, seed plate count, and green and yellow seed count for safe storage (Rajarammanna et al., 2010).

1.3.1 Moisture content

Moisture content specifies the amount of water in seeds. During storage, while samples stored in the environment which is highly humidified, it can lead to availability of unbound water in the seed. As a result, few changes such as moisture migration, ingress of precipitation, initial damp grain might potentially occur (Chelladurai et al., 2016; Copeland & Macdonald, 2001). Due to this higher moisture content, a hot spot is developed that can be favorable for the growth of insects, mites and micro-organisms which factors for grain deterioration. For this reason, grain stored at higher moisture is likely to spoil faster than at lower moisture. Studies showed that seeds at lower moisture content lead the grain to a longer period of storage with little deterioration (Sun, 1999; Zomorodian et al., 2011). However, for oilseeds, the range of this low moisture content for safe storage is different than for cereals. There is a big difference in buffer limit between cereals and oilseeds with small changes of moisture content. Cereals have the buffer limit within the response in ERH to changing moisture content which is very small in oilseeds due to the presence of high oil content. Hence, spoilage can occur in oilseed at lower moisture content level because they contain less carbohydrates (Cassells et al., 2003). Researchers (Cassells et al., 2003; Diosady et al., 1996; Sun, 1999; Sun & Byrne, 1998; Zomorodian et al., 2011) studied some factors (surrounding air relative humidity, air temperature, seed variety, degree of seed maturity) determining moisture isotherms of oilseeds that indicated significant influence at different times during storage. Another study by Ellis et al., (1991) proposed that oil palm seeds should be dried to critical moisture content (defined as 11% moisture content in equilibrium with RH at 20°C) below which the viability equation was not applicable. As hemp seed also is oil seed, therefore, to keep safe during storage, moisture should be lower than for oil palm. .

1.3.2 Equilibrium Relative Humidity (water activity)

Equilibrium relative humidity is another important factor as it controls the availability of water inside the stored grain seed (Krist & Nichols, 1999; Sauer, 1988; Wilson, 1999). Most stored products are hygroscopic and can sorb moisture or give it up to the atmosphere until being in equilibrium with the relative humidity. At equilibrium condition, ERH inside the air is the same as the water activity inside the grain kernels. As already mentioned, the amount of water inside the seeds means moisture content that is intertwined with optimum ERH suggested by Singh et al., (2017). This optimum ERH is below 65% that controls moisture content between 19 and 27% considered as safe MC for storage in soybean. Nevertheless, higher RH directly influences seed stability and quality through the changes of some factors such as (1) undesirable chemical reactions, (2) the activity of enzymes, and (3) physical properties (texture and moisture migration) that affect growing of various microorganisms over the storage period (Bhat & Reddy, 2017; Christensen, 1957; Karunakaran et al., 2001; Wagner et al., 2017). Therefore, the studies suggested that lower RH (≤50%) was good to maintain considering germination index and rate of seedling growth over the storage period (Pixton & Warburton, 1971).

1.3.3 Temperature

Temperature is one of the most important factors that influence the quality of seeds during storage. Researchers studied (Diosady et al., 1996; Kawamoto et al., 1991; Pixton & Warburton, 1971; Schroth, 1996; Sonawane, 1979; Sun, 1999; Sun & Byrne, 1998; Viravanichai, 1971; Zomorodian et al., 2011) the changes of moisture content as well as temperature in oilseeds and found that there is a strong correlation between them. The rate of oxygen uptake is strongly correlated with the seed moisture content and temperature in oilseeds. Seeds with high temperature always have a higher respiratory quotient than those with lower temperature (Cassells et al., 2003; Diosady et al., 1996). As a result, microbes produce heating in wet grain that can rise to 75℃. However, if a temperature below 10℃ is maintained, most of the common storage fungi, except *Penicillium*, will not grow (Singh et al., 2017). Therefore, lower temperature is suggested for safe and long-term storage especially for oilseeds like hemp.

1.4 Factors used to evaluate grain quality

1.4.1 Germination

The visible protrusion of any seed growth is defined as germination (Black, 1970) that is also considered as an indicator of living grain generally expressed as percentages (%). Germination is the external biological expression of physiological, biochemical and morphological changes of a seed through transformation into a seedling (Al-Yahya, 2001; Kandil et al., 2013; Sholberg, 1975). Seed size, shape and structures are some of those physiological factors that can affect germination by allowing the seed to easily gain or lose moisture (Strenske et al., 2017). This moisture is one of the external factors that influences the germination. Other external factors are relative humidity, temperature, respiration, light (Riungu, 1984; Roberts, 1960; Strenske et al., 2017; Viravanichai, 1971; Yaciuk, 1973) and the action of fungi and bacteria (Krist & Nichols, 1999; Wagner et al., 2017). Many studies have already been done on those factors determining viability of various grains. Kreyger (1972) studied the effect of many levels of moisture content and temperature on seed germination percentage in which he concluded that longer storage times are possible with lower moisture contents.

Therefore, these external factors must be considered during storage and duration is one of the important factors that indicates how long would germination remain good. (Al-Yahya, 2001; Kandil et al., 2013). Another study found storage longevity is positively associated with good germination under hospitable temperature and moisture content (Kandil et al., 2013). However, dockage could potentially be another factor that influences germination during storage probably not on a small scale but in a large bin. Usually, the more grain, the higher the chances of influence by the presence of dockage which could produce hot spot. Therefore, evaluation of germination could directly indicate safe and unsafe conditions for storage. .

1.4.2 Fatty acid value (FAV)

Seed longevity is associated with the seed aging process that can lead to seed deterioration through lipid oxidation and associated free radical oxidative stresses (Crapiste et al., 1999; Stewart & Bewley, 1980). In hemp seed, it contains omega-3 and omega-6 fatty acids (*Canadian Hemp*

Nature's wonder fibre, 1998). Fatty acids are esterified to glycerol and varies in chain length and saturation degree (saturated, mono or polyunsaturated) (Nagaraj, 2009; Priestley & Leopold, 1983; Stewart & Bewley, 1980; Young, 1994). In oilseeds, saturated fatty acids mostly are palmitic and stearic acids as well as unsaturated fatty acids such as oleic, linoleic and linolenic acids. The concentration of fatty acids consists of these two types (saturated and unsaturated) acids wherein increasing the number of unsaturated fatty acid increases the fluidity of the lipid (Izquierdo et al., 2017). The oxidation of oil requires oxygen that comes from the atmosphere if seeds are exposed to air storage (Crapiste et al., 1999; Schukla et al., 1992; Stefansson, 1966). Unsaturated fatty acids are prone to oxidation due to the presence of double bond on it (Singh et al., 2017). Researchers (Crapiste et al., 1999; Hummel et al., 1954; Stewart & Bewley, 1980; Warner et al., 1989; Young, 1994) found that free fatty acids are an intermediate product during spoilage in stored grain. Chemical changes of stored grain might be proportional to the moisture content that influences the amount of fatty acid (Canvin, 1965; Karunakaran, 1999). Microfloral growth is related to decay and some species of molds produce large amounts of free fatty acids (Hummel et al., 1954; Ma et al., 2017; Wilson, 1999). Lower the germination rate is related to high free fatty acid levels.

The mechanism of lipid oxidation depends on high temperature and availability of oxygen. The oxidation of lipids could be enzymatic or non-enzymatic to deteriorate seeds over the storage time (Murthy & Sun, 2000; Stewart & Bewley, 1980). Enzymatic (by lipoxygenase) and non-enzymatic (auto-oxidation) both might occur (Singh et al., 2017). Oxygen (O_2) is integrated with unsaturated fatty acid through dimerization (linoleic) and polymerization (linolenic) reactions to form hydroperoxides (H_2O_2), producing a weight gain that practically remains constant in oil samples (Stewart & Bewley, 1980). Molds produce free fatty acids by hydrolysis.

The development of rancidity occurs during storage. In storage, higher relative humidity increases moisture content that favors activity of lipolytic enzymes. These lipolytic enzymes are partially liable for the increment of FFA content in oil (Schukla et al., 1992). In the oil industry, the level of FFA is a quality parameter to determine the loss of oil quality at harvest and post-harvest that rapidly occurs at high moisture and temperature (Cassells et al., 2003). High temperatures accelerate the rate of oxidation of lipids and the absence of oxygen can inhibit the process (Singh et al., 2017). Studies showed that oilseed (soybean) contains high levels of oxidation of unsaturated fatty acid through oxidation process at high temperature and high relative humidity (Stewart & Bewley, 1980). Studies showed that high lipid seeds had lower thresholds for respiration and required lower moisture contents for optimum storage (Priestley & Leopold, 1983). Moreover, changes in lipid composition, unpleasant taste and odors; degradation of functional and nutritional properties are consequences of oxidation or hydrolysis. Furthermore, the non-glyceride part of oil (free fatty acids) can produce oil soluble pigments that darkens the color of the oil (Schukla et al., 1992). Therefore, FAV can be used as a measure of deterioration in grain.

1.4.3 Visible or invisible mold

To maintain grain quality, a visual test is one of the important steps during grain storage. For that time being, visible mold is appeared. Under any storage condition, the discoloration of grain is likely to occur from the growth of mold that could possibly be visible or invisible under the seed coat. During storage, some grains in a large bin are made up into small pockets with discoloration. It is generally found to be warmer than other adjacent places. These small pockets are considered as hotspots. The grain from this hotspot must be tested for quality purposes. Wet grain mainly produces microorganisms in those hotspots as they need ≥ 0.65 water activity (65% RH) to be developed (Jarvis, 1971; Sauer, 1988). While microorganisms grow up, they produce heat that can generate more hotspots through a self-accelerating process within the bin. Further study on rapid microorganism growth showed that the more hotspots in grain bin, the more spoilages are caused that reflects mold growth (Bhat & Reddy, 2017; Fleurat-Lessard, 2017). Therefore, visible and invisible mold is a good determinant for determining the grain quality.

1.4.4 Seed plate (bacteria) count

Bacteria plays an important role in the deterioration of wet seeds during storage. Bacteria can deteriorate the seeds quality immediately before and after harvest (Krist & Nichols, 1999; Wagner et al., 2017). Conditions of the abiotic environment of grain such as temperature and moisture content must be suitable for biotic agents to spoil grain (Al-Yahya, 2001; Kandil et al., 2013; Roberts, 1960; Viravanichai, 1971). There are many methods to determine bacteria on seeds. One is the traditional method, where the number of colonies forming units are counted for quality assurance of seeds. Another is culture-based analysis where the number of grown bacterial cells are identified. To investigate depth on the actual physiological state and metabolic activities of the cell, fluorescent stains can be used which enable detecting viable, damaged, and dead bacterial cells with the help of fluorescent light (Saarela, 2007). Researchers found that plate count is the most acceptable method to measure infestation based on deposition both specific and total microorganisms on agar in a petri dish. The higher the number of colonies found in seeds, the more the grain has spoiled over the storage period.

1.4.5 Green and yellow seed count

Green seeds are immature seeds and identified when crushed. Seed quality was negatively affected, and chlorophyll contents incremented with the increase in the percentage of green seed (Pádua et al., 2007). While many bulks contain 2 to 6% green seeds, financial penalties are imposed to a grower by the Canadian Grain Commission because of additional refining cost (Smolikova et al., 2017). The chances of having more percentages of green seed would be higher if the crop is frozen prematurely in the fields. On the other hand, there are many reasons for having yellow seeds in oilseeds such as unfavorable storage conditions (extremely hot and dry); premature harvesting; uncontrolled conditions during storage and so on. To have safe storage, the percentage of green and yellow seeds should be as low as possible. Despite few studies done on green seed count especially on hemp seed, researchers (Cenkowski et al., 1989) concluded leaving canola seeds for 4 days in swath in the field, that lowers the amount of green seed. Moreover, long term storage can also reduce the green seed slightly as it matures. However, it is still unknown whether the yellow and green seed count of the stored hemp seed will change under different storage conditions, but it can be a predictor for grain quality determination.

1.4.6 Storage period and safe storage guidelines

The longevity of seeds throughout the storage is defined as seed storability (Copeland & Macdonald, 2001; Desai, 1997; Kandil et al., 2013; Šimić et al., 2007). The quality of stored grain depends on several factors such as temperature, seed moisture content, relative humidity, and storage period. High temperature and high relative humidity are considered as adverse conditions for safe storage and are liable to changes of moisture content as well as of biochemical process in seeds (Riungu, 1984; Roberts, 1960; Strenske et al., 2017). Hence, it is ineffective to determine the feasible storage period without these factors (Šimić et al., 2007; Singh et al., 2017). Extensive studies have already been conducted on those factors in different grains such as wheat (Yokoyama et al., 1997), rapeseed (Mills & Sinha, 1980), canola meal (Jayas et al., 1989), wild rice and rice (White & Jayas, 1996), hull-less and hulled oats and barley (White et al., , 1999),and flax seed (White & Jayas, 1991). At present, there is a lack data regarding the storability of hemp seed at different temperatures and moisture contents. There are studies on hemp seed as a nutritional aspect (Callaway, 2002, 2004), a raw material for industrial purpose (Ranalli & Venturi, 2004), physical and mechanical properties (Taheri-Garavand et al., 2012).

Therefore, the present study to develop the safe storage guidelines by investigating the effect of temperature, relative humidity, and storage period along with three dockage levels (0, 5, and 15) %.

2 MATERIALS AND METHODS

2.1 Hemp seed with dockage

A popular variety of hemp seed known as FINOLA® - was obtained from a farm located 20 km south west of Winnipeg, Manitoba. The harvested hemp seed were dried at room conditions (25 ±3℃, 30 to 40% RH) for 0, 4, 6, and 8 days. . About 10 g seed was placed in a hot air oven at 103℃ for 5 h to determine the moisture content. The hemp seed were cleaned by using a hand sieve (no. 14, 5.56 mm opening) to separate the larger chaff, and then was further cleaned by using a three-dimensional shaker (Sweco® Vibro-Energy® Separators, Sweco, Florence, USA) with a no.10 sieve (2.032 mm). The desired amount of dockage was mixed with the cleaned hemp seed to produce the hemp seed with 5 and 15% (weight basis) dockage. For example, to produce 5% dockage of hemp seed, 50 g dockage were mixed with 950 g cleaned seeds in a mixer (Big Cat, Type B, Red Lion, Inc., Winnipeg, Manitoba, Canada). The dockage used in this study were the dockages collected during the above-mentioned cleaning process and from a grain elevator when hemp seed were loaded into an elevator bin.

The required moisture content (±0.2% for all moisture levels) for the study were achieved by adding the desired amount of distilled water to the hemp seed samples; and then stored in a plastic bag at 5℃ ±2℃. To ensure the uniform moisture distribution, the samples were mixed again 3 d later. The moisture content was determined 1 wk later, and this moisture content was reported in this thesis. Initially, the moisture contents of the hemp seed used for this study were: (16%, 14%, 12%, and 10%) ±0.3%. The samples were stored in plastic bags at 5℃ ±2℃ for at least 2 wk until use.

2.2 Storage factors measured

Five different temperatures and four relative humidities with three levels of dockage percentages were considered. The dockage levels were 0%, 5%, and 15%. The temperatures were 20, 25, 30, and 35℃. Relative humidity of the hemp samples were achieved by using four salt solutions: KNO_3, NaCl, $NaNO_2$ and Mg $(NO_3)_2$ to produce 94, 75, 65, and 54% RH, respectively (Winston & Bates, 1960). As there was no established equation on isotherms of hemp seed, the isotherm equation of canola was used to estimate the initial moisture content of hemp seed. Throughout the storage period, the moisture content of hemp seed at 54, 65, 75, and 94% RH was estimated as 9, 10, 12.5, and 15%, respectively.

2.3 Experimental set up

All the experiments were conducted under controlled environmental conditions. Five environmental chambers were used to maintain 20, 25, 30, and 35℃ within ±1℃. Plastic pails were used to hold about 2 L salt solution at the bottom of the pails (Fig. 1). In each pail, there were three small PVC pipes to support the mesh plate. Three mesh bags (each bag contained 1 kg of seeds) were located on the mesh plate. The top of the pails was loosely covered by a lid. About 33 g of samples were taken at regular intervals to analyze moisture content (10 g), germination (1 g), visible mold (1 g), other microflora (11 g) and green and yellow seed count (10 g). . There were three replicates for each treatment.

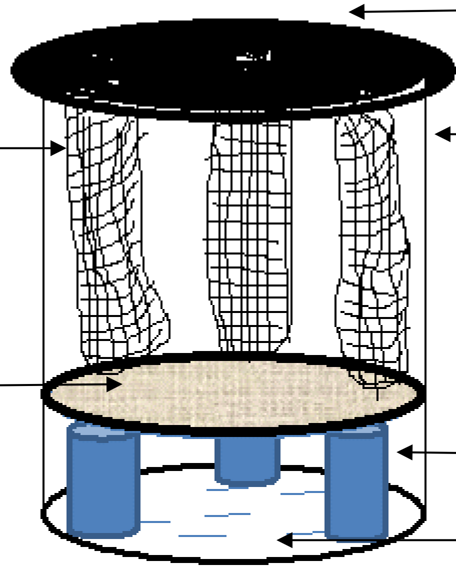


Fig. 1 Schematic diagram of the experimental set up of hemp samples in pail

2.3.1 Seed quality assessment

The following parameters were measured: moisture content, seed germination, visible and invisible mold, FAV, seed plate (bacteria) count, and green and yellow seed count. The first four factors were analyzed at the University of Manitoba and the other two factors were conducted by Hemp Oil Canada (Winnipeg, Manitoba, Canada). To assess the grain quality, a schedule was prepared giving priority to higher RH and higher temperature. The schedule was revised based on 20% initial germination loss. For instance, the first modification was done at 9 wk storage time. The treatment at 35℃ and 14.3% initial moisture content was terminated because the germination loss was higher than 20%.

The change in seed germination over time was tested according to the method of Wallace and Sinha (1962). In (100 mm X 15 mm) Petri dishes, 25 seeds were placed on a Whatman no. 3 filter paper saturated with 5.5 mL of distilled water. If any dockage dropped with seeds on the soaked paper, it kept for the test. The Petri dishes were vertically stacked in a stand; and to prevent desiccation of the filter paper, the stacked dishes were covered with a polyethene bag. This set up was incubated at 25℃ for 7 days. The number of seeds germinated after 7 days was counted and the germination (%) was determined.

Table 2 Sample frequency and sampling schedule during the entire study period

Schedule modification time (wk) [a]	Initial M.C (%)	Temperature (℃)			
		20[b]	25[b]	30[b]	35[b]
0	16	2	1	1	1
	14	3	2	2	1
	12	4	3	2	2
	10	4	4	3	2
9	16	2	1	1	—
	14	2	2	2	1
	12	3	3	2	1
	10	4	4	3	2
11	16	1	1	—	—
	14	2	1	1	—
	12	3	2	2	1
	10	3	3	3	2
12	16	1	1	—	—
	14	1	1	—	—
	12	2	2	1	—
	10	3	3	3	2
14	16	1	—	—	—
	14	1	1	—	—
	12	2	2	1	—
	10	2	2	2	1
17	16	—	—	—	—
	14	1	1	—	—
	12	2	2	1	—
	10	2	2	2	—

[a] the numbers of 0, 9, 11, 12, 14 and 17 indicated the sampling frequency was modified at the storage time 0, 9, 11, 12, 14 and 17 wk, respectively.

[b] number inside each column represents the sample frequency. For example, “4” indicated that sampling was conducted for every 4 wk. “—” indicated no sampling was conducted because the germination was ≤ 40%.

2.3.2 Fatty acid value

The Goldfisch fat extractor method was used (American Association of Cereal Chemists procedure, 1962). A Stein mill (M-2, Fred Stein Laboratories, Inc, Atchinson, KS) was used to grind the samples which were collected after moisture content measurement. Five-gram ground samples were taken by weighing and rolled in Whatman no.5 filter paper. This was placed inside a glass cylinder and put into the fat extractor (Goldfisch Fat Extractor, Laboratory Construction Co, Kansas City, MO) with 30 mL of petroleum ether solvent in beakers. The Fat extractor machine ran 6 h to segregate oil into the solvent. Afterwards, the oil was separated from the solvent by heating it again and then 25 mL of TAP solution (50% toluene and 50% ethanol with phenolphthalein indicator) was added to the oil. A KOH solution of known normality was used for titration until the appearance of a pale pink color; and the FAV value was expressed as mg KOH/100 g dry seed.

2.3.3 Visible and invisible mold

The deterioration of the grain samples was inspected by visual inspection of the samples for the determination of visible mold. For identification of the invisible microfloral species, 25 seeds were placed in a (100 mm X 15 mm) Petri dish with Whatman no. 3 filter paper saturated with 5.5 mL of 7.5% aqueous sodium chloride (NaCl) solution. The Petri dishes were stacked vertically in stands; covered with plastic bags; and incubated at 25℃ for 7 days. The number of seeds infected after 7 d were identified using a dissection microscope (C-PS, SMZ 1000, Nikon, Melville, NY). Then, infested seeds were counted as percentages in favor of various species.

2.3.4 Seed plate (bacteria) count

To determine aerobic bacteria in hemp seed, agar was used with parafilm. The 1 mL samples were placed onto plates containing a cold water-soluble gelling agent and an indicator called TTC (2,3,5-triphenyl tetrazolium chloride). A plastic spreader was used to spread the sample over 20 cm^2 and the gelling agent worked to solidify the sample. Then, plates were incubated only at 25 ℃ out of all temperatures (20 to 35℃) and counted. The whole process was done by following the procedure published by Warburton (2001) and presented in Appendix E.

2.3.5 Green and yellow seed count

A two-by-ten-inch plastic paddle and vinyl roller were used to determine green and yellow seeds from samples. Hemp seed were placed on the paddle and then masking tape was used to keep those seeds over the paddle. Afterwards, a vinyl roller was used to crush the sample to expose color of the seed flesh that was counted as percentage. A representative sample of about 250 seeds were taken out from each small bag (0 to 15% dockages) to analyze. This test was done on only 25℃.

2.4 Statistical analysis

The statistical analysis was performed using Statistical Analysis Software (SAS version 9.4, Statistical Analysis Systems Institute, Inc, Cary, NC). To determine the effect of dockage levels on the equilibrium moisture content under the same temperatures and RH, paired t-tests were conducted along with the storage time. The same analysis was done for seed plate (bacteria) count and green and yellow seed count. Three-way ANOVA and MANOVA were conducted to determine the effect of the following factors on germination, FAV, and the growth of the species of visible and invisible mold: temperature, relative humidity, and dockage percentage. During these ANOVA and MANOVA analyses, the data at the storage periods of 4, 6, 8 and 10 wk were used.

3 RESULTS AND DISCUSSION

3.1 Equilibrium moisture content

The equilibrium moisture content was 14.3±0.5, 12.4±0.4, 10.1±0.1, 9±0.9 at 94%, 75%, 65% and 54% RH, respectively. The hemp seed lost moisture regardless of the initial MC like canola (Jian et al., 2014). More importantly, the extent of losing moisture in hemp seed was faster than canola (Sun & Byrne, 1998). The EMC (%) of the hemp seed with 0% dockage was significantly different from the seeds with 15% dockage at the same temperature and RH (Table 3). Therefore, the presence of dockage could influence the moisture content of the stored hemp seed. Under any percentage of dockage, hemp seed must be kept at ≤25℃ and ≤70% RH to get ≤10% EMC over storage period. The moisture content of the hemp seed had a faster increase under higher temperature and RH, for example at 35℃ and ≥70% RH than that at the lower temperature and RH. This is consistent with the literature (Šimić et al., 2007; Sun, 2014).

Table 3 Effect of dockage on equilibrium moisture content (paired t-test)

Comparison [a]		t	$Pr > \lvert t \rvert$
0	5	-1.78	0.076
5	15	-0.25	0.804
15	0	2.9	0.004*

[a] Comparison between two dockage percentages under the same temperature and RH.

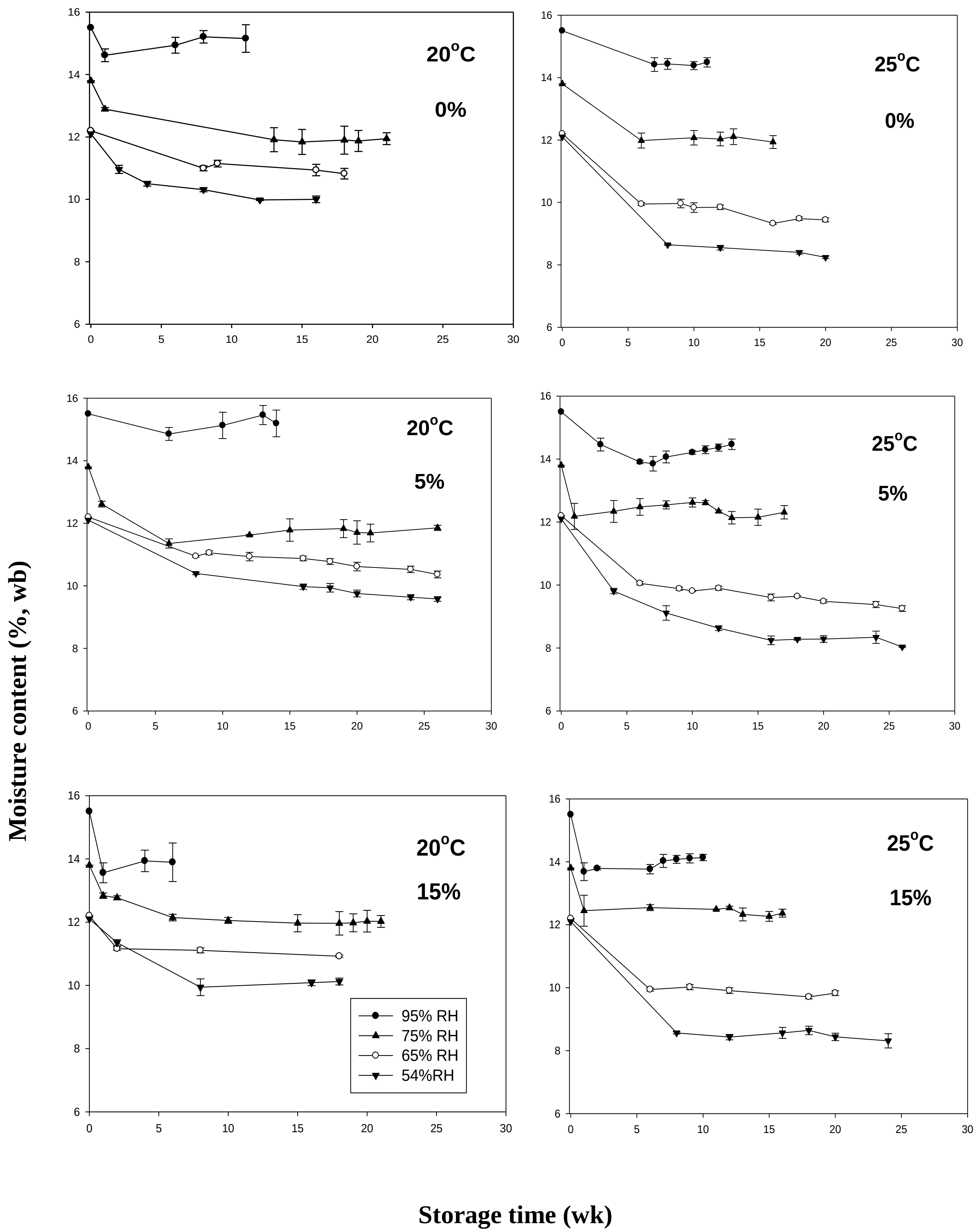
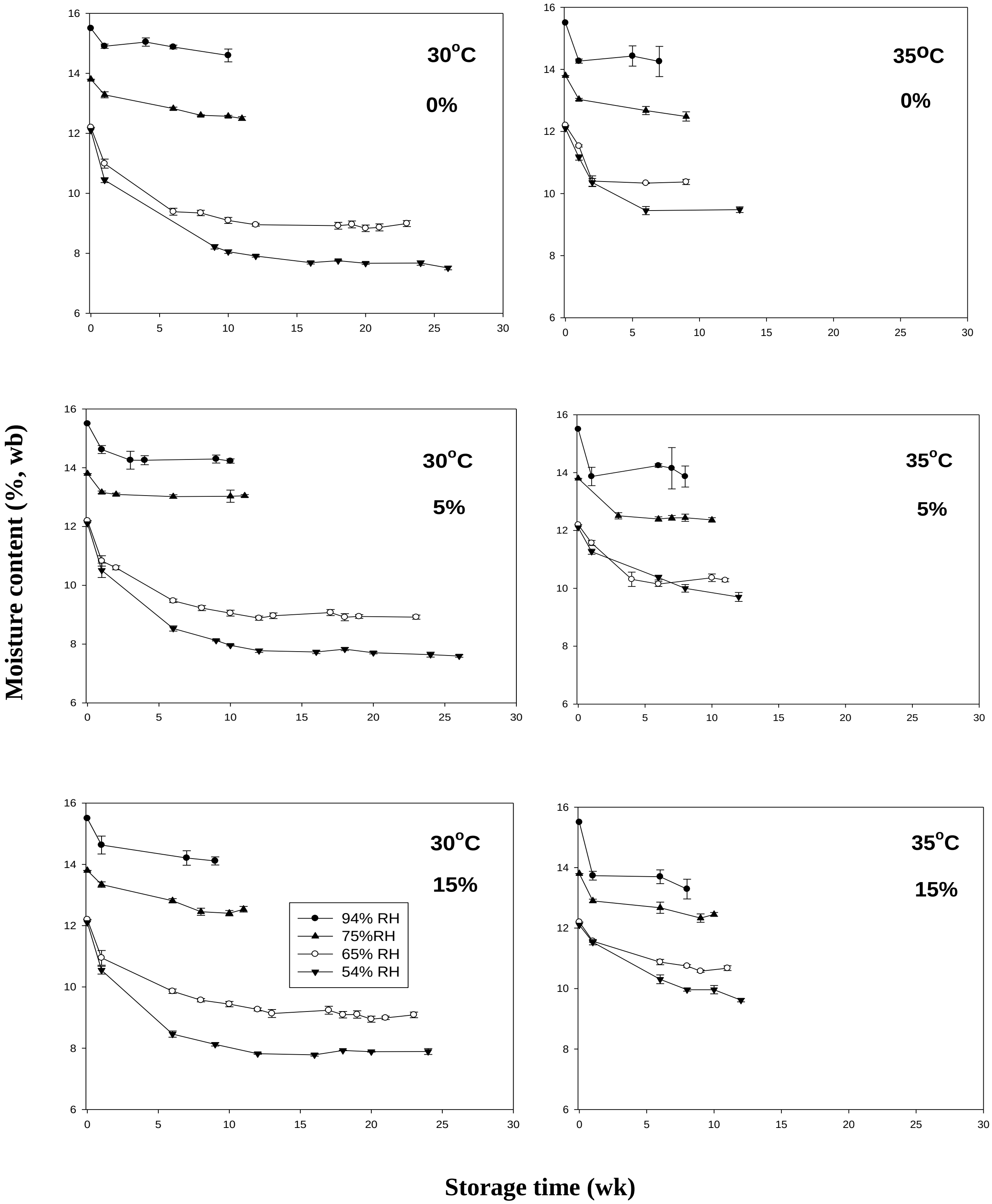


Fig. 2 Moisture content of hemp seed with different dockage percentages (0, 5, and 15%), temperatures, and storage times.



Continuation of Fig. 2 Moisture content of hemp seed with different dockage percentages (0, 5, and 15%), temperatures, and storage times.

3.2 Germination

3.2.1 Effect of dockage

Table 4. ANOVA tests on the effect of storage factors on germination of hemp seed with different percentages of dockage

Storage factor	DF	F	P> F
Temperature	3	255.81	<.0001*
RH	3	210.03	<.0001*
Dockage	2	5.95	0.004*
Temperature*RH	9	12.56	<.0001*
Temperature*Dockage	6	0.29	0.939
RH*Dockage	6	1.02	0.415
Temperature*RH*Dockage	18	2.08	0.012*

The initial germination was 94 ±2%. The hemp seed stored at three levels of dockages showed significant difference in germination along with the increase of storage time (Table 4). The higher percentages of dockage, the higher germination loss. However, there was no interaction effect on the germination between percentage of dockage and temperature or RH.

3.2.2 Effect of relative humidity

Relative humidity was one of the main factors influencing the germination along with the increase of storage time (Table 4). This result was consistent with the literature on wheat (Al-Yahya, 2001), soybean (Kandil et al., 2013), and rapeseeds (Kawamoto et al., 1991). In our study, germination of the samples stored at 90% RH (15.5% MC) and at 35℃ was dropped down more than 50% in the first week. A similar result was observed by Sholberg (1975) on cereal grains, rapeseed, and fababeans. But, germination of the samples stored at ≤70% RH (10% MC) and at 35℃ dropped only 14% from its initial level in the first week. Therefore, less than 70% RH would be safe for hemp seed storage.

3.2.3 Effect of temperature

Germination decreased over the storage period at all temperatures. It decreased more rapidly at higher temperatures than lower temperatures (Fig. 3). This result is the same as reported by Sun (2014). In our study, germination of the samples stored at ≤70% RH and at 25℃ was more than 50% germination in the end of the storage (26 wk). Therefore, the mean germination of hemp seed would be >80% while samples were stored at ≤25℃.

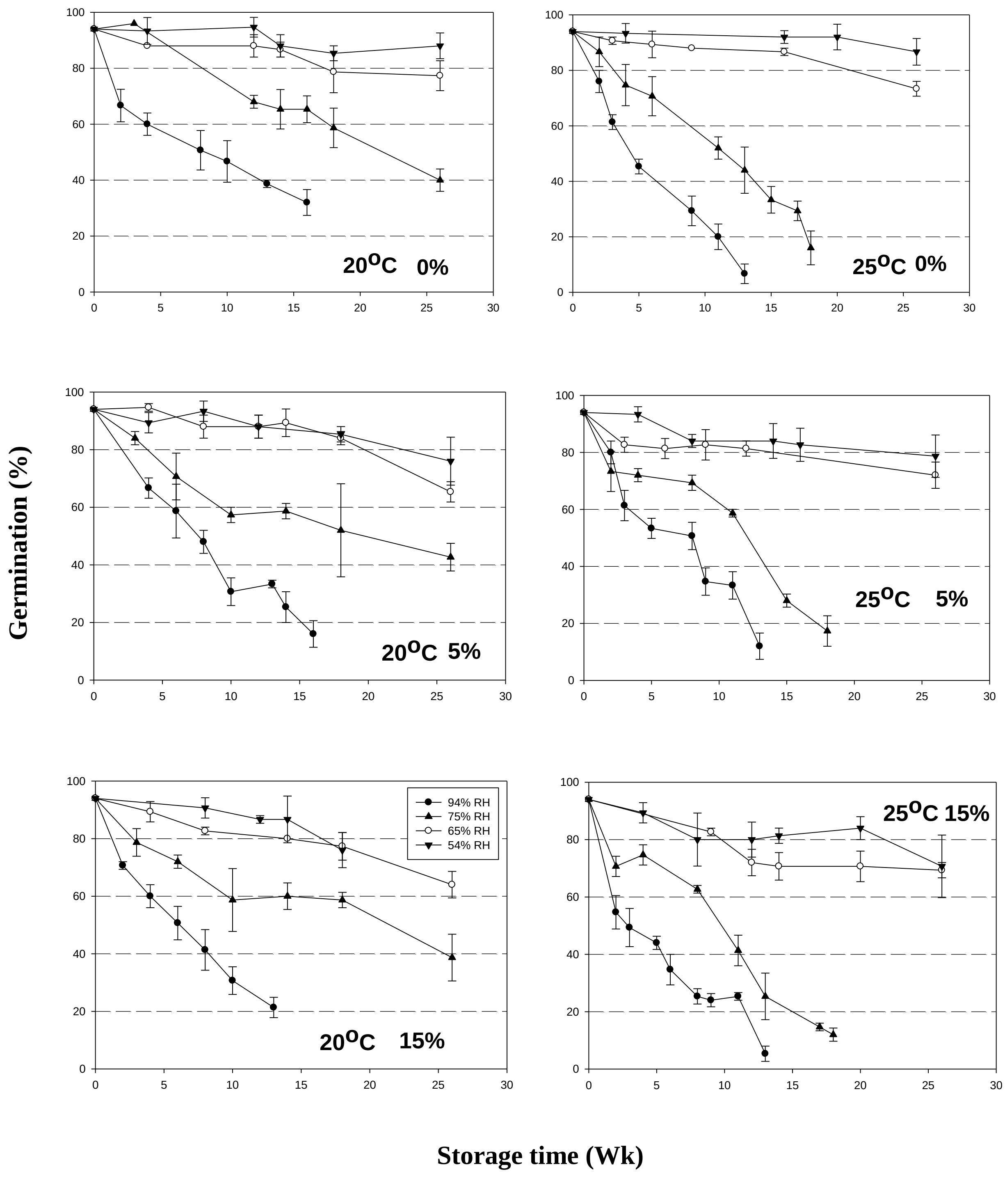
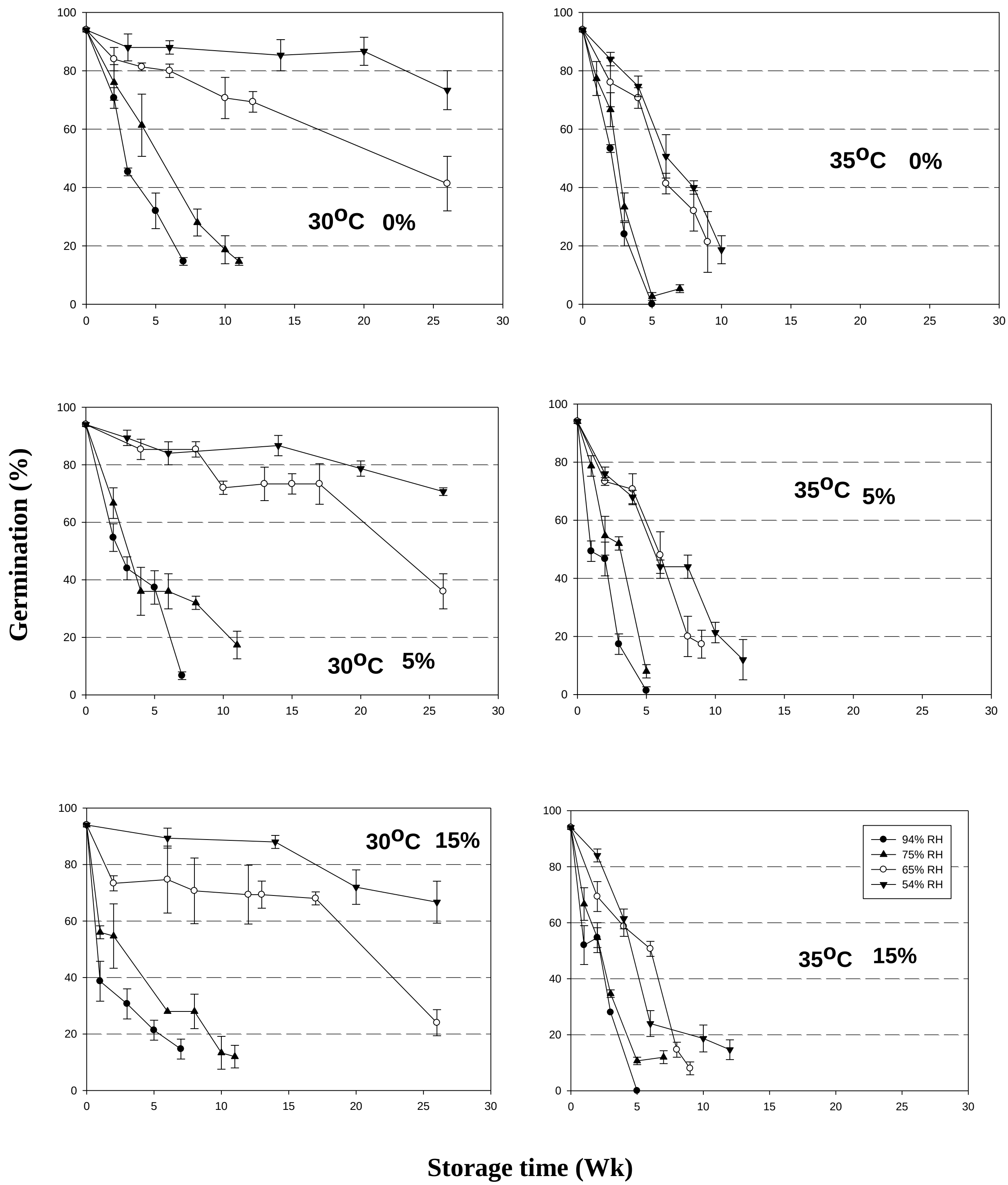


Fig. 3 Germination of hemp seed under different dockage percentages (0, 5, and 15%), temperatures, and storage times.



Continuation of Fig. 3 Germination of hemp seed under different dockage percentages (0, 5, and 15%), temperatures, and storage times.

3.3 Free fatty acid value

3.3.1 Effect of dockage

Table 5. ANOVA tests on the effect of storage factors on Free fatty acid value of hemp seed with different percentage of dockage

Source	DF	F	P> F
Temperature	3	158.25	<.0001*
RH	3	1566.3	<.0001*
Dockage	2	1.3	0.277
Temperature*RH	9	59.04	<.0001*
Temperature*Dockage	6	2.28	0.042*
RH*Dockage	6	1.68	0.133
Temperature*RH*Dockage	18	0.97	0.503

The initial FAV was (50.8 ±2.5) mg/100g of dry mass. The hemp seed stored at three levels of dockages showed no significant difference in FAV along with the increase of storage time (Table 5). As dockage itself had low oil content that would not increase FAV, this result was consistent with the literature (Dickson, 2014; Schukla et al., 1992; Stefansson, 1966).

3.3.2 Effect of relative humidity

Relative humidity was one of the main factors influencing the FAV over the storage time (Table 5). This result was consistent with the literature on rapeseed (Mills & Sinha, 1980), wheat (Karunakaran et al., 2001) and soybean (Stewart & Bewley, 1980). The higher the RH, the higher the FAV. In our study, FAV of the samples stored at 90% RH (15.5% MC) and at 35℃ increased about 28 times of the initial FAV in 3 wk. Higher relative humidity causes enzymes to be more active that favors the increase of FFA content in oil (Schukla et al., 1992). But, FAV of the samples stored at 70% RH (12% MC) and at 35℃ was only 3 times the initial FAV in 10 wks. Therefore, less than 70% RH would be safe for hemp seed storage.

3.3.3 Effect of temperature

Free fatty acid value increased over the storage period regardless of temperature. But, it increased more rapidly at higher temperature than lower temperature (Fig. 4). This result is the same as reported by Rajarammanna et al. (2010).

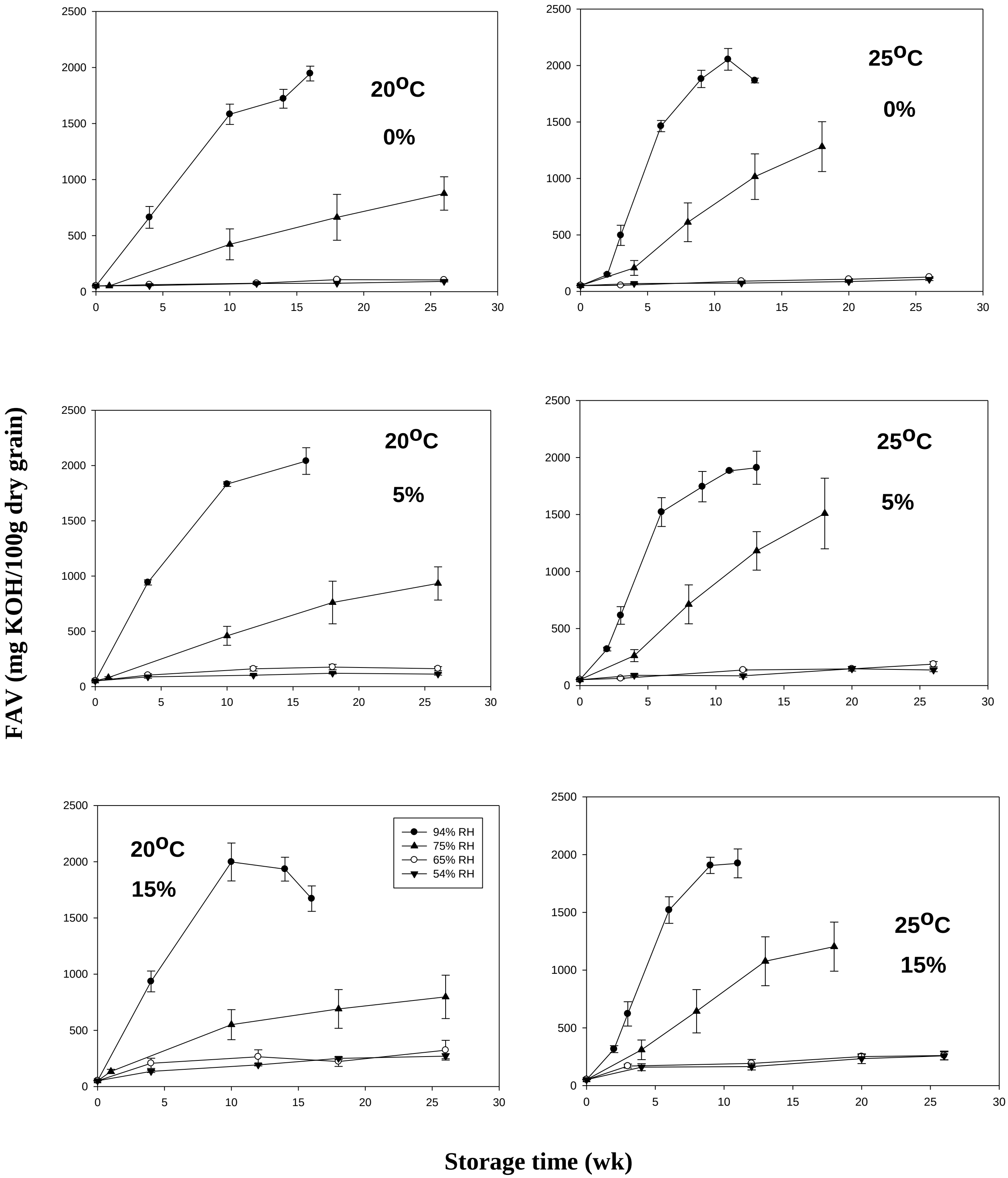
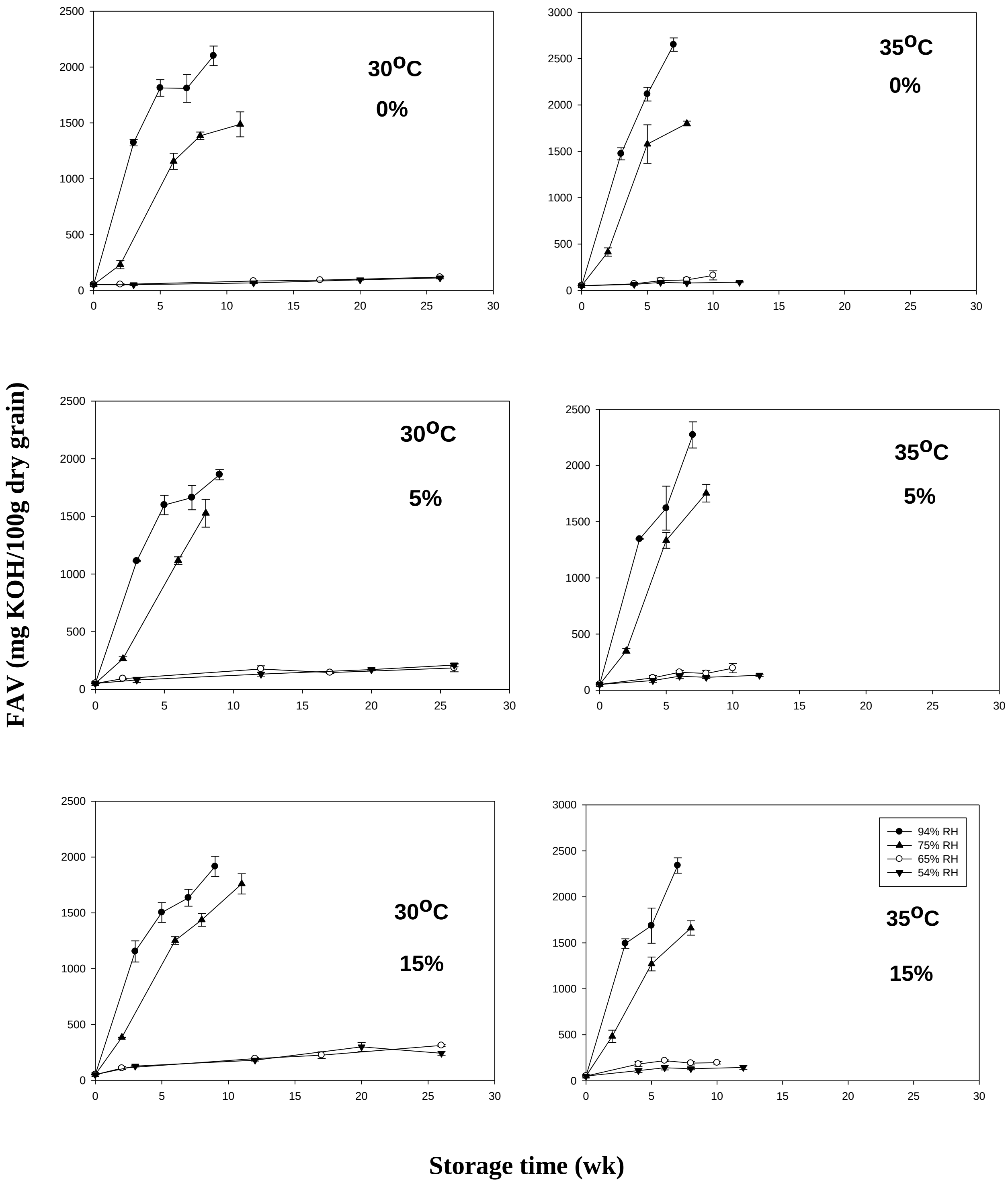


Fig. 4. Fatty acid value of hemp seed under different dockage percentages (0, 5, and 15%), temperatures, and storage times.



Continuation of Fig. 4. FAV of hemp seed under different dockage percentages (0, 5, and 15%), temperatures, and storage times.

In our study, FAV of the samples stored at 54% RH and at 30℃ was increased by 2.6 times of its initial FAV by the end of the storage (26 wk). This result was consistent with the literature (Reuss and Cassells, 2003). But, FAV of the samples stored at 54% RH and at 20℃ increased only 2 times of its initial FAV in the same storage time (26 wk). Samples stored at high temperature are being accelerated by the oxidation of lipids by lipolytic enzymes (Cassells et al., 2003). Therefore, lower temperature (≤25℃) would be the best condition to lessen FAV in hemp seed.

3.4 Visible and invisible mold

3.4.1 Effect of dockage

Initially, there was no visible and invisible mold in the hemp seed. The hemp seed stored at three levels of dockages showed no significant difference in mold along with the increase of storage time (Table 6).

Table 6 MANOVA tests on the effect of storage factors on invisible mold of hemp seed with different percentages of dockage

Source	DF	*Alternaria*		*Aspergillus flavus*		*Aspergillus candidus*		*Aspergillus ochraceus*		*Aspergillus wentii*		*Penicillium*	
		F	**P> F**	**F**	**P> F**	**F**	**P> F**	**F**	**P> F**	**F**	**P> F**	**F**	**P> F**
Temperature	3	78.97	<.0001*	26.18	<.0001*	34.92	<.0001*	12.24	<.0001*	7.12	0.0002*	99.58	<.0001*
RH	3	71.1	<.0001*	42.83	<.0001*	15.64	<.0001*	3.33	0.023*	3.56	0.017*	58.27	<.0001*
Dockage	2	2.28	0.107	3.92	0.023*	2.54	0.084	1.58	0.211	0.15	0.862	1.88	0.158
Temperature*RH	9	34.37	<.0001*	40.68	<.0001*	79.96	<.0001*	6.26	<.0001*	3.56	0.001*	43.91	<.0001*
Temperature*Dockage	6	1.13	0.351	1.15	0.342	1.61	0.152	1.34	0.247	0.15	0.989	2.12	0.058
RH*Dockage	6	2.21	0.048*	1.71	0.126	4.02	0.001*	2.72	0.018*	0.74	0.617	0.9	0.498
Temperature*RH*Dockage	18	3.83	<.0001*	2.39	0.004*	1.98	0.018*	2.1	0.012*	0.74	0.760	2.39	0.004*

Effect of dockage percentages on the multiplication of mold was not studied on hemp seed. Researchers studied the effect of other factors (temperature, RH) on visible and invisible mold in wheat (Karunakaran, 1999), hull-less and hulled oats and barley (White et al., 1999), and rapeseed (Mills & Sinha, 1980). There was an interaction between percentage dockage and RH in a few species (*Alternaria; Aspergillus candidus; and Aspergillus ochraceus*) of visible and invisible mold.

3.4.2 Effect of relative humidity

Both temperature and relative humidity significantly influenced the mold multiplication. Researchers studied moisture isotherm that described the relationship between grain moisture and ERH to determine mold (fungi) (Cassells et al., 2003); on antifungal potential for storage of wheat seeds (Anžlovar et al., 2017); and on foods (Barbosa-Cánovas et al., 2007). The higher the RH, the higher the chances of there being spoilage. In our study, samples stored at 90% RH (15.5% MC), mold was visible by the first week. This result was consistent with the literature (Jarvis, 1971). Therefore, hemp seed stored at higher RH should be dried immediately.

3.4.3 Effect of temperature

At all temperatures, mold was seen over the storage period. It was seen at the first week at 35°C (Fig. 5).

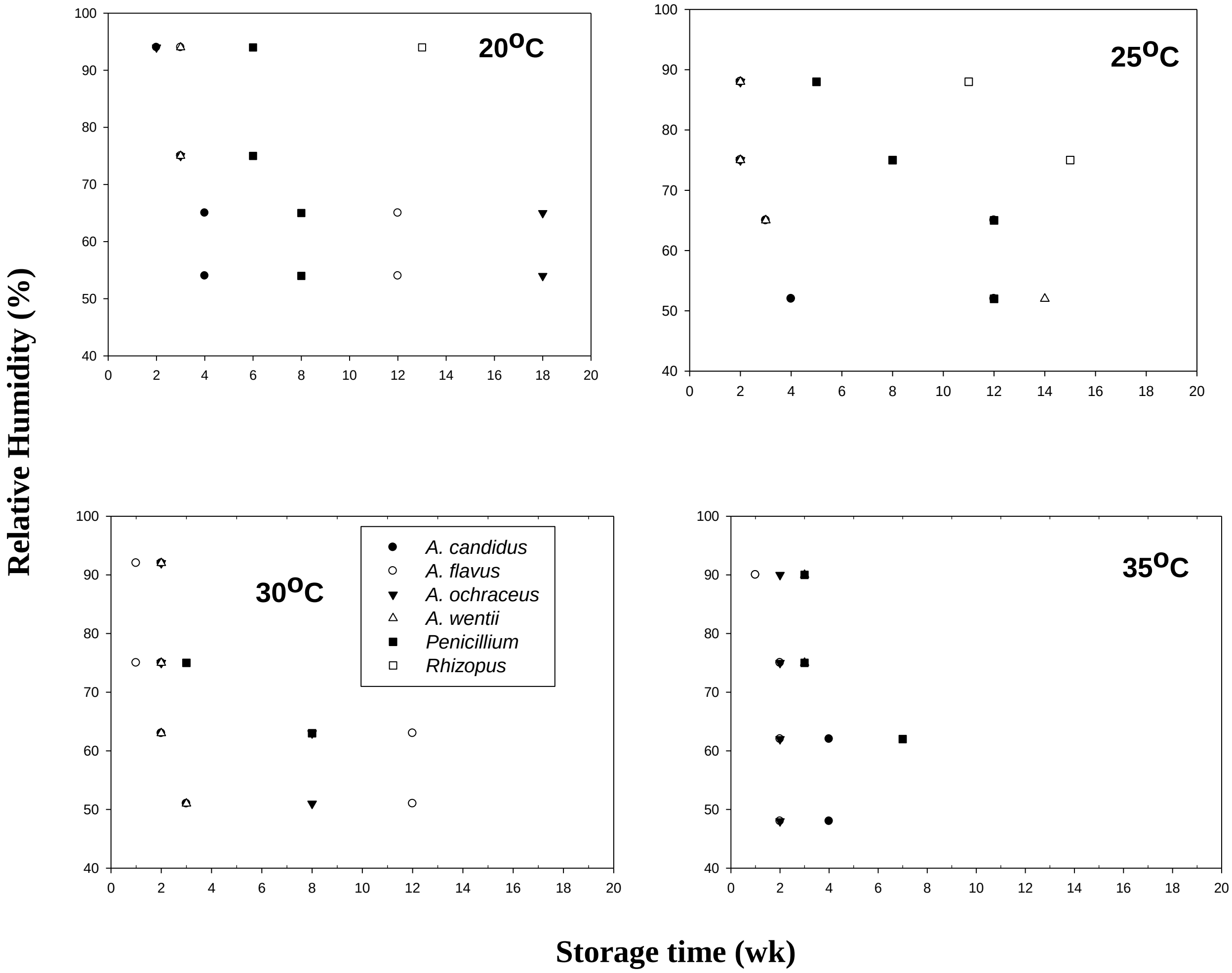


Fig. 5. Various mold appearance of hemp seed with respect to different relative humidity in temperatures, and storage times.

In our study, *A. flavus* and *A. candidus* were seen mostly at all temperatures regardless of RH. *Aspergillus ochraceus* and *A. wentii* were seen after *A. flavus* and *A. candidus* throughout the study. *Penicillium* was seen early at higher temperature and higher RH than lower temperature and lower RH. *Rhizopus* was not seen at all temperatures. Therefore, low temperature (≤25°C) would be the best storage condition to prevent the multiplication of mold.

3.5 Seed plate (bacteria) count

Dockage levels had significant influence on seed plate (bacteria) count (Table 7, Fig 6). Numbers of colonies in seed plate (bacteria) count at any dockage level increased rapidly regardless of relative humidity (Fig 6).

Table 7. Results of pairwise comparisons of dockage percentages for seed plate count using paired t-test at 25℃

Comparison [a]		t	Pr > |t|
0	5	-2.07	0.043*
5	15	-3.47	0.001*
15	0	4.47	<.0001*

[a] Comparison between two dockage percentages under the same RH.

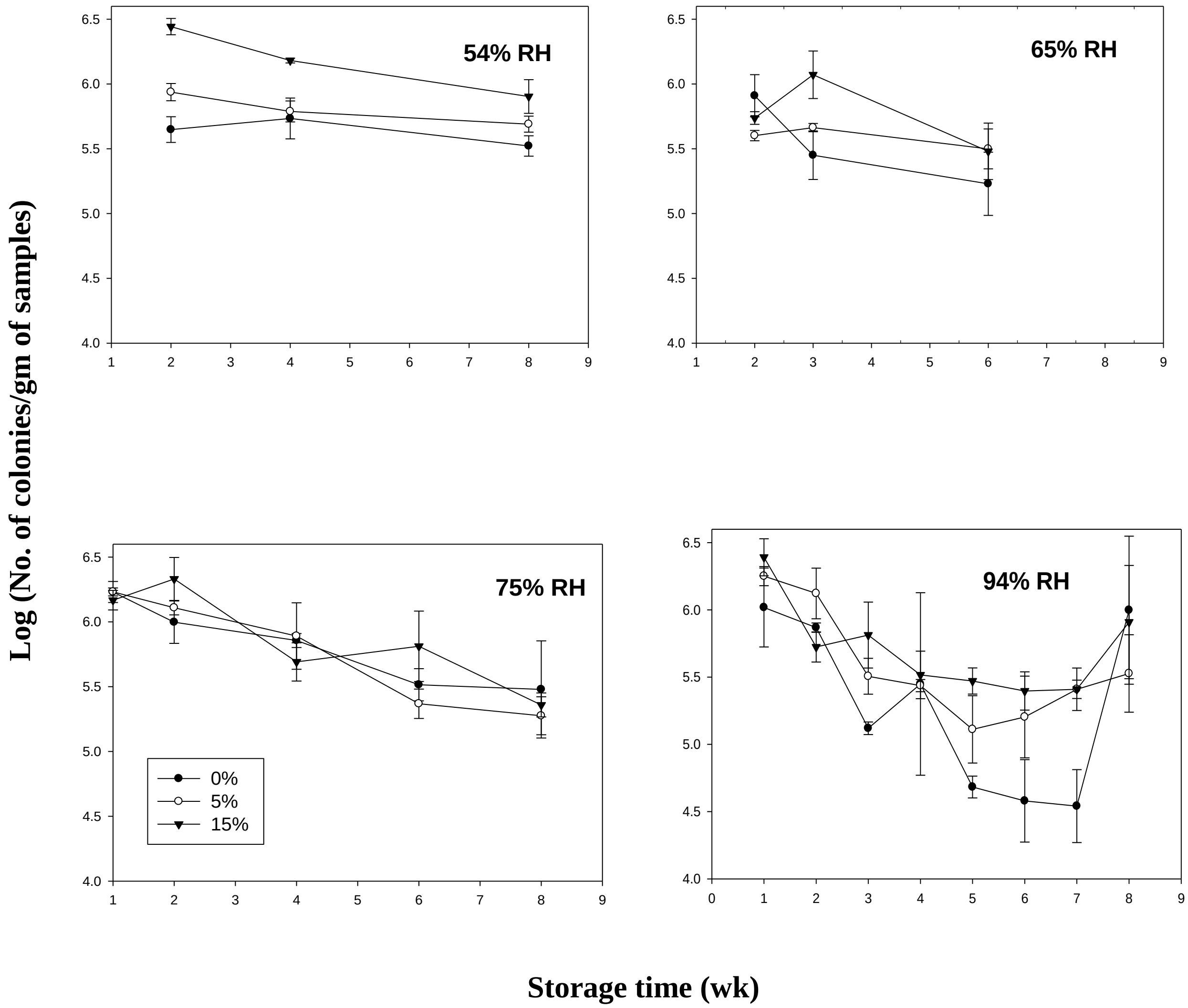


Fig. 6. Changes in Seed Plate Count of hemp seed with respect to dockage percentages (0, 5, and 15%) and storage time at 53, 64, 75, and 93% RH in 25℃

The higher dockage level, the higher the CFU (Table 7). Therefore, the best environmental conditions for storage of hemp seed with minimized undesirable microbial changes would be low dockage percentages (<15%) along with low relative humidity (<53%) which create a less hospitable environment for microorganisms to grow (Bhat & Reddy, 2017; Wagner et al., 2017).

3.6 Green and yellow seed count

Dockage levels did not influence the green and yellow seed count (Table 8). Percentages of yellow seeds at any dockage level went down when RH was <70%, while they increased at 93% RH (Fig 7).

Table 8. Results of pairwise comparisons of dockage percentages on green and yellow seed count using paired t-test at 25℃

Comparison		t	Pr > |t|
0	5	1.38	0.175
5	15	-1.08	0.287
15	0	-0.43	0.667

[a] Comparison between two dockage percentages under the same RH.

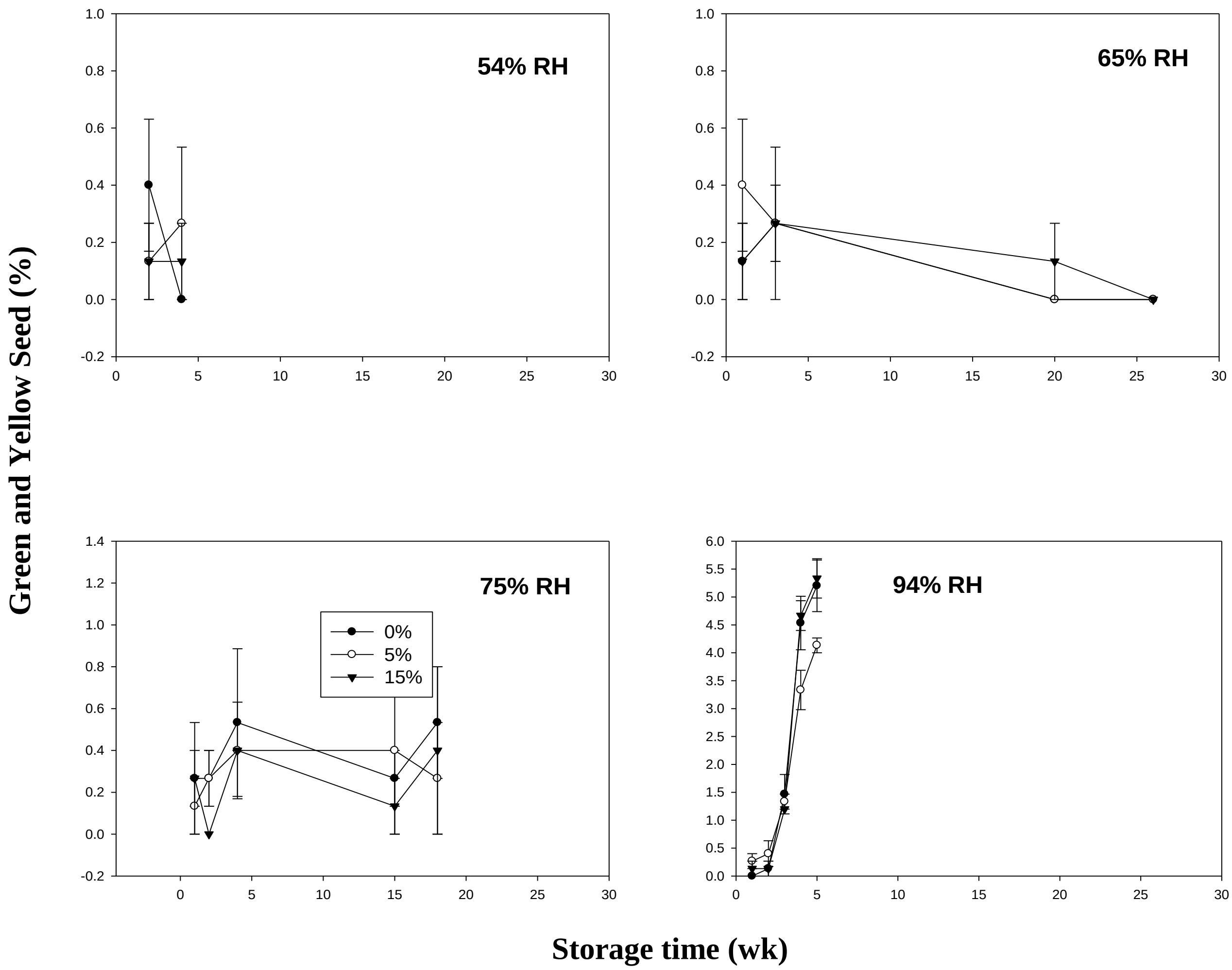


Fig. 7 Changes in Green and yellow seed count of hemp seed with respect to dockage percentages (0, 5, and 15%) and storage time at 53, 64, 75, and 93% RH in 25℃

Immature hemp seed might have a post maturity period under dry storage conditions, while hemp seed stored over 70% RH, it showed more yellow seeds over storage period. It might be occurred due to spoilage in higher RH. (Barthet, 2017).

3.7 Estimated safe storage life

In this study, the safe storage period (Fig. 8) was defined as the time of 20% germination loss from its initial germination and no appearance of visible mold. Estimated safe storage periods for hemp seed were divided into three levels of dockages because dockage percentages influenced the germination. Hemp seed if dockage is $\leq$15% with <70% RH at $\leq$25℃ would be the ideal environment for safe storage of hemp seed.

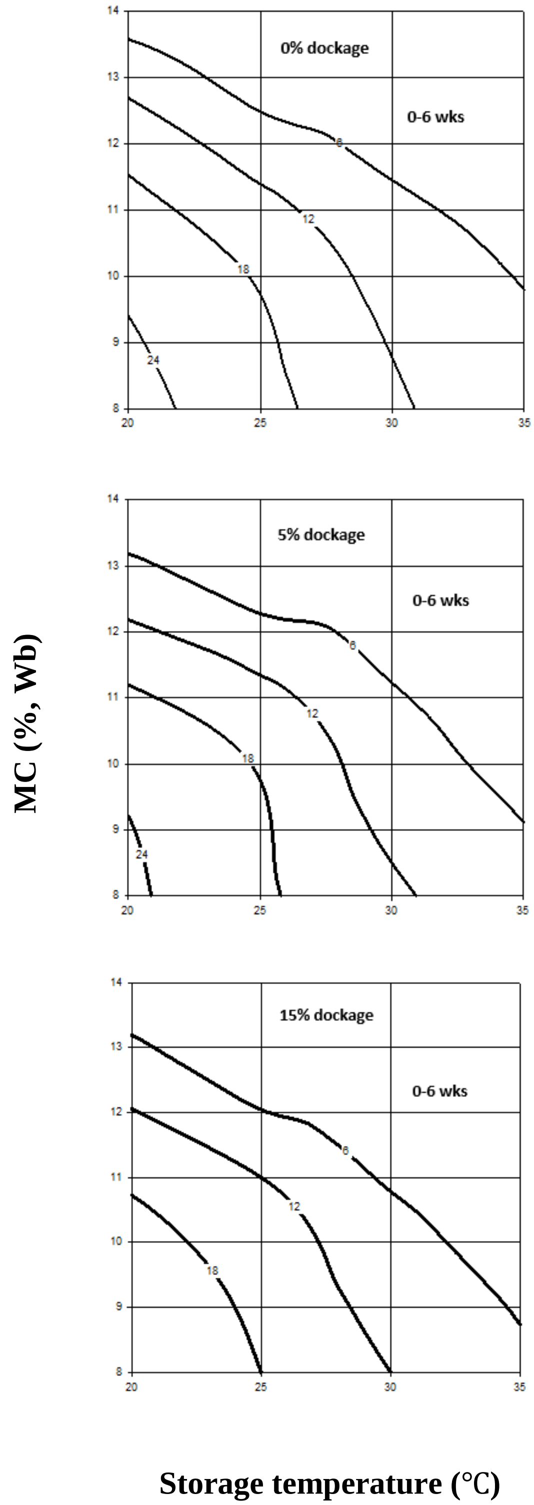


Fig. 8 Estimated safe storage life of hemp seed based on 20% initial germination loss and no visible mold. Numbers on graphs are indicated as wk of safe storage

At 0% dockage, at ≤25℃, hemp seed with ≤ 9.5% MC could safely be stored for >24 wk. However, at the same condition, hemp seed with 13.5% MC could only be safely stored for 4 wk. In ≤15% dockage, at ≤25℃, hemp seed must be stored at ≤9%.

4 CONCLUSIONS

1. Hemp seed stored at <65% RH and <25℃ would have good storage quality up to 6 months.

2. Less than 9% moisture content were considered as safe storage moisture content at any dockage percentages.

3. At 75% RH, *Aspergillus flavus* was first seen in week 1, 2, and 3 at 30, 25, and 20℃, respectively. Nonetheless, it was first seen at week 12 when hemp seed were stored at <65% RH and 30℃.

4. First appearance of invisible mold was delayed with the decrease of moisture contents and temperature.

5. Hemp seed stored at 20℃ had FAV 10 times higher at 88% RH than that at <63% RH.

6. Percentages of dockages and RH did not influence the number of colonies of bacteria and number of yellow seeds at 25℃.

7. Increase of dockage percentage would result in a short safe storage time. To store the hemp seed with 5% dockage for >24 wks, temperature must be ≤20℃ and moisture content must be ≤9%. At the same storage condition, the hemp seed with 15% dockage could only be safely stored for ≤ 20 wk.

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APPENDIX A: MOISTURE CONTENT DATA

Table A1. Moisture content of hemp seed stored at 20℃ in 0% dockage

Storage period (Weeks)	RH	Moisture content (%, Wb)			Mean	S.D.
		R1	R2	R3		
0	94	15.5	15.5	15.5	15.5	0.0
1	94	14.8	14.8	14.2	14.6	0.4
6	94	15.1	15.2	14.4	14.9	0.4
8	94	14.9	15.1	15.6	15.2	0.3
11	94	14.3	15.8	15.3	15.2	0.8
0	75	13.8	13.8	13.8	13.8	0.0
1	75	12.9	13.0	12.8	12.9	0.1
13	75	12.1	11.2	12.5	11.9	0.7
15	75	12.1	11.1	12.4	11.8	0.7
18	75	12.1	11.0	12.6	11.9	0.8
19	75	12.1	11.2	12.4	11.9	0.6
21	75	12.1	11.6	12.1	12.0	0.3
0	65	12.2	12.2	12.2	12.2	0.0
8	65	11.0	10.9	11.1	11.0	0.1
9	65	11.4	11.1	11.0	11.2	0.2
16	65	11.3	10.8	10.7	10.9	0.3
18	65	11.1	10.8	10.6	10.8	0.3
0	54	12.1	12.1	12.1	12.1	0.0
2	54	11.2	11.0	10.7	11.0	0.2
4	54	10.7	10.5	10.4	10.5	0.1
8	54	10.4	10.3	10.2	10.3	0.1
12	54	10.0	10.0	10.0	10.0	0.0
16	54	9.8	10.2	10.0	10.0	0.2

R1, R2, and R3 = replicate 1, 2, and 3 respectively. All are the same in these appendixes.

Table A2. Moisture content of hemp seed stored at 20℃ in 5% dockage

Storage period (Weeks)	RH	Moisture content (%, Wb)			Mean	S.D.
		R1	R2	R3		
0	94	15.5	15.5	15.5	15.5	0.0
6	94	15.2	14.8	14.5	14.9	0.3
10	94	14.3	15.5	15.7	15.0	0.7

13	94	15.3	16.1	15.1	15.5	0.5
14	94	14.5	16.0	15.1	15.2	0.7
0	75	13.8	13.8	13.8	13.8	0.0
1	75	12.5	12.8	12.5	12.6	0.2
6	75	11.6	11.3	11.1	11.4	0.2
12	75	11.7	11.6	11.6	11.6	0.0
15	75	12.0	11.1	12.2	11.7	0.6
19	75	12.0	11.3	12.2	11.8	0.5
20	75	12.0	11.0	12.1	11.6	0.6
21	75	12.1	11.1	11.8	11.7	0.5
26	75	11.7	11.9	12.0	11.8	0.1
0	65	12.2	12.2	12.2	12.2	0.0
8	65	10.9	11.0	10.9	11.0	0.0
9	65	10.9	11.2	11.1	11.1	0.1
12	65	11.2	10.8	10.8	11.0	0.2
16	65	11.0	10.8	10.8	10.9	0.1
18	65	11.0	10.7	10.6	10.8	0.2
20	65	10.9	10.5	10.5	10.6	0.2
24	65	10.7	10.5	10.4	10.6	0.2
26	65	10.5	10.1	10.5	10.3	0.2
0	54	12.1	12.1	12.1	12.1	0.0
8	54	10.4	10.3	10.4	10.4	0.1
16	54	10.0	10.1	9.8	10.0	0.1
18	54	9.9	10.2	9.8	10.0	0.2
20	54	9.8	9.9	9.5	9.8	0.2
24	54	9.7	9.8	9.5	9.7	0.1
26	54	9.5	9.7	9.6	9.6	0.1

Table A3. Moisture content of hemp seed stored at 20℃ in 15% dockage

Storage period (Weeks)	RH	Moisture content (%, Wb)			Mean	S.D.
		R1	R2	R3		
0	94	15.5	15.5	15.5	15.5	0.0
1	94	13.6	14.1	13.0	13.7	0.4
4	94	14.6	13.5	13.8	14.0	0.6
6	94	14.2	14.8	12.7	14.1	0.8
0	75	13.8	13.8	13.8	13.8	0.0
1	75	12.8	13.0	12.7	12.9	0.1
2	75	12.7	12.9	12.7	12.8	0.1
6	75	11.9	12.3	12.2	12.1	0.2
10	75	11.9	12.2	12.0	12.1	0.2
15	75	12.1	11.5	12.4	11.9	0.4

18	75	12.0	11.3	12.6	11.8	0.5
19	75	11.9	11.5	12.5	11.9	0.4
20	75	12.1	11.4	12.6	11.9	0.5
21	75	12.1	11.7	12.3	12.0	0.3
0	65	12.2	12.2	12.2	12.2	0.0
2	65	11.2	11.3	11.1	11.2	0.1
8	65	11.1	11.0	11.3	11.1	0.1
18	65	11.0	10.9	10.9	10.9	0.1
0	54	12.1	12.1	12.1	12.1	0.0
2	54	11.5	11.2	11.3	11.4	0.2
8	54	9.4	10.3	10.1	9.9	0.5
16	54	10.0	10.3	10.0	10.1	0.2
18	54	10.0	10.3	10.1	10.1	0.2

Table A4. Moisture content of hemp seed stored at 25℃ in 0% dockage

Storage period (Weeks)	RH	Moisture content (%, Wb)			Mean	S.D.
		R1	R2	R3		
0	93	15.5	15.5	15.5	15.5	0.0
7	93	14.7	14.0	14.6	14.4	0.4
8	93	14.3	14.8	14.2	14.4	0.3
10	93	14.5	14.5	14.1	14.4	0.2
11	93	14.8	14.4	14.3	14.5	0.3
0	75	13.8	13.8	13.8	13.8	0.0
6	75	12.5	11.8	11.7	12.0	0.4
10	75	12.5	11.8	11.9	12.1	0.4
12	75	12.5	11.8	11.8	12.0	0.4
13	75	12.6	12.1	11.7	12.1	0.4
16	75	12.3	11.8	11.6	11.9	0.4
0	64	12.2	12.2	12.2	12.2	0.0
6	64	10.0	9.9	9.9	10.0	0.1
9	64	10.2	9.9	9.8	10.0	0.2
10	64	10.1	9.7	9.6	9.8	0.3
12	64	9.9	9.9	9.7	9.9	0.1
16	64	9.4	9.3	9.4	9.3	0.1
18	64	9.4	9.6	9.4	9.5	0.1
20	64	9.5	9.5	9.3	9.4	0.1
0	53	12.1	12.1	12.1	12.1	0.0
8	53	8.6	8.7	8.6	8.6	0.0
12	53	8.7	8.6	8.4	8.6	0.1
18	53	8.4	8.5	8.3	8.4	0.1
20	53	8.2	8.3	8.3	8.2	0.1

Table A5. Moisture content of hemp seed stored at 25℃ in 5% dockage

Storage period (Weeks)	RH	Moisture content (%, Wb)			Mean	S.D.
		R1	R2	R3		
0	93	15.5	15.5	15.5	15.5	0.0
3	93	14.6	14.8	14.1	14.5	0.3
6	93	14.0	13.9	13.9	13.9	0.1
7	93	14.3	13.5	13.8	13.9	0.4
8	93	13.8	14.0	14.4	14.0	0.3
10	93	14.3	14.2	14.1	14.2	0.1
11	93	14.2	14.2	14.5	14.2	0.2
12	93	14.6	14.3	14.3	14.4	0.2
13	93	14.1	14.6	14.6	14.4	0.3
0	75	13.8	13.8	13.8	13.8	0.0
1	75	12.3	12.9	11.4	12.3	0.6
4	75	12.8	12.6	11.7	12.5	0.5
6	75	12.9	12.6	12.0	12.6	0.4
8	75	12.7	12.7	12.3	12.6	0.2
10	75	12.7	12.8	12.3	12.7	0.2
11	75	12.7	12.7	12.5	12.6	0.1
12	75	12.4	12.3	12.4	12.3	0.1
13	75	12.5	12.2	11.8	12.2	0.3
15	75	12.6	12.1	11.7	12.2	0.4
17	75	12.6	12.4	11.9	12.4	0.3
0	64	12.2	12.2	12.2	12.2	0.0
6	64	10.1	10.2	10.0	10.1	0.1
9	64	10.0	9.8	9.9	9.9	0.1
10	64	9.8	9.9	9.8	9.8	0.0
12	64	10.0	9.8	9.8	9.9	0.1
16	64	9.6	9.8	9.4	9.6	0.2
18	64	9.6	9.7	9.7	9.6	0.0
20	64	9.6	9.5	9.4	9.5	0.1
24	64	9.5	9.2	9.5	9.4	0.2
26	64	9.4	9.3	9.1	9.3	0.1
0	53	12.1	12.1	12.1	12.1	0.0
4	53	9.9	9.6	9.9	9.8	0.1
8	53	9.6	9.0	8.8	9.2	0.4
12	53	8.8	8.6	8.5	8.7	0.1
16	53	8.1	8.5	8.1	8.3	0.2
18	53	8.2	8.3	8.3	8.3	0.1

20	53	8.1	8.4	8.4	8.3	0.2
24	53	8.1	8.7	8.2	8.4	0.3
26	53	8.0	8.1	8.0	8.0	0.0

Table A6. Moisture content of hemp seed stored at 25℃ in 15% dockage

Storage period (Weeks)	RH	Moisture content (%, Wb)			Mean	S.D.
		R1	R2	R3		
0	93	15.5	15.5	15.5	15.5	0.0
1	93	13.2	13.6	14.2	13.6	0.4
2	93	13.8	13.7	13.8	13.8	0.1
6	93	14.1	13.5	13.7	13.8	0.3
7	93	14.2	13.6	14.3	14.0	0.3
8	93	14.3	13.9	14.0	14.1	0.2
9	93	14.0	14.4	14.0	14.1	0.2
10	93	14.3	14.0	14.1	14.1	0.2
0	75	13.8	13.8	13.8	13.8	0.0
1	75	12.7	13.2	11.5	12.6	0.7
6	75	12.7	12.5	12.4	12.6	0.1
11	75	12.5	12.5	12.5	12.5	0.0
12	75	12.4	12.6	12.6	12.5	0.1
13	75	12.6	12.5	11.9	12.4	0.3
15	75	12.6	12.1	12.2	12.3	0.3
16	75	12.2	12.6	12.3	12.4	0.2
0	64	12.2	12.2	12.2	12.2	0.0
6	64	9.9	10.0	9.9	10.0	0.1
9	64	10.2	10.0	9.9	10.0	0.1
12	64	10.1	9.9	9.8	9.9	0.1
18	64	9.8	9.8	9.6	9.7	0.1
20	64	9.8	10.0	9.7	9.9	0.1
0	53	12.1	12.1	12.1	12.1	0.0
8	53	8.6	8.5	8.6	8.6	0.1
12	53	8.5	8.3	8.5	8.4	0.1
16	53	8.5	8.9	8.3	8.6	0.3
18	53	8.5	8.9	8.6	8.7	0.2
20	53	8.2	8.6	8.5	8.4	0.2
24	53	8.1	8.8	8.0	8.4	0.4

Table A7. Moisture content of hemp seed stored at 30℃ in 0% dockage

Storage period (Weeks)	RH	Moisture content (%, Wb)			Mean	S.D.
		R1	R2	R3		
0	92	15.5	15.5	15.5	15.5	0.0
1	92	14.9	14.8	15.0	14.9	0.1
4	92	15.2	14.8	15.2	15.0	0.2
6	92	14.8	14.8	15.0	14.9	0.1
10	92	14.4	14.4	15.0	14.6	0.4
0	75	13.8	13.8	13.8	13.8	0.0
1	75	13.2	13.5	13.2	13.3	0.2
6	75	12.9	12.8	12.8	12.8	0.1
8	75	12.6	12.6	12.6	12.6	0.0
10	75	12.6	12.6	12.5	12.6	0.1
11	75	12.5	12.6	12.4	12.5	0.1
0	63	12.2	12.2	12.2	12.2	0.0
1	63	11.3	10.8	10.9	11.0	0.3
6	63	9.6	9.3	9.3	9.4	0.2
8	63	9.4	9.4	9.2	9.3	0.2
10	63	9.3	9.0	9.1	9.1	0.2
12	63	9.0	9.0	8.9	9.0	0.1
18	63	9.2	8.8	8.8	8.9	0.2
19	63	9.2	8.8	8.9	9.0	0.2
20	63	9.0	8.7	8.8	8.8	0.2
21	63	9.1	8.7	8.8	8.9	0.2
23	63	9.2	8.9	8.9	9.0	0.2
0	51	12.1	12.1	12.1	12.1	0.0
1	51	10.5	10.3	10.6	10.4	0.1
9	51	8.3	8.2	8.1	8.2	0.1
10	51	8.1	8.1	7.9	8.1	0.1
12	51	8.0	7.8	7.9	7.9	0.1
16	51	7.8	7.6	7.7	7.7	0.1
18	51	7.8	7.7	7.8	7.8	0.0
20	51	7.7	7.6	7.7	7.7	0.1
24	51	7.6	7.6	7.8	7.7	0.1
26	51	7.5	7.4	7.6	7.5	0.1

Table A8. Moisture content of hemp seed stored at 30℃ in 5% dockage

Storage period (Weeks)	RH	Moisture content (%, Wb)			Mean	S.D.
		R1	R2	R3		
0	92	15.5	15.5	15.5	15.5	0.0
1	92	14.7	14.4	14.8	14.6	0.2
3	92	14.7	14.4	13.7	14.4	0.4
4	92	14.1	14.1	14.6	14.2	0.2
9	92	14.3	14.5	14.1	14.3	0.2
10	92	14.2	14.2	14.4	14.2	0.1
0	75	13.8	13.8	13.8	13.8	0.0
1	75	13.3	13.1	13.1	13.2	0.1
2	75	13.0	13.1	13.2	13.1	0.1
6	75	13.1	12.9	13.1	13.0	0.1
10	75	13.4	13.1	12.7	13.1	0.3
11	75	13.1	13.0	13.0	13.1	0.1
0	63	12.2	12.2	12.2	12.2	0.0
1	63	11.2	10.7	10.6	10.9	0.3
2	63	10.7	10.5	10.5	10.6	0.1
6	63	9.6	9.4	9.4	9.5	0.1
8	63	9.4	9.2	9.1	9.3	0.1
10	63	9.3	9.0	8.9	9.1	0.2
12	63	9.0	8.8	8.9	8.9	0.1
13	63	9.2	8.9	8.8	9.0	0.2
17	63	9.3	9.0	8.9	9.1	0.2
18	63	9.1	8.9	8.7	9.0	0.2
19	63	9.1	8.9	8.9	9.0	0.1
23	63	9.1	8.9	8.8	8.9	0.1
0	51	12.1	12.1	12.1	12.1	0.0
1	51	10.7	10.0	10.8	10.5	0.4
6	51	8.7	8.6	8.4	8.6	0.1
9	51	8.2	8.1	8.1	8.1	0.0
10	51	8.0	7.9	8.0	8.0	0.0
12	51	7.9	7.7	7.8	7.8	0.1
16	51	7.8	7.7	7.7	7.8	0.1
18	51	7.9	7.7	7.8	7.8	0.1
20	51	7.8	7.6	7.7	7.7	0.1
24	51	7.6	7.6	7.8	7.6	0.1
26	51	7.5	7.6	7.7	7.6	0.1

Table A9. Moisture content of hemp seed stored at 30℃ in 15% dockage

Storage period (Weeks)	RH	Moisture content (%, Wb)			Mean	S.D.
		R1	R2	R3		
0	92	15.5	15.5	15.5	15.5	0.0
1	92	14.1	14.9	15.0	14.6	0.5
7	92	13.8	14.4	14.5	14.2	0.4
9	92	13.9	14.4	14.0	14.1	0.2
0	75	13.8	13.8	13.8	13.8	0.0
1	75	13.5	13.4	13.2	13.4	0.1
6	75	12.7	12.7	13.0	12.8	0.1
8	75	12.2	12.6	12.6	12.4	0.2
10	75	12.2	12.5	12.5	12.4	0.1
11	75	12.7	12.5	12.4	12.6	0.2
0	63	12.2	12.2	12.2	12.2	0.0
1	63	11.3	10.5	11.1	10.9	0.4
6	63	10.0	9.8	9.8	9.9	0.1
8	63	9.7	9.5	9.5	9.6	0.1
10	63	9.6	9.3	9.4	9.5	0.2
12	63	9.3	9.2	9.3	9.3	0.1
13	63	9.4	9.0	9.0	9.2	0.2
17	63	9.5	9.0	9.2	9.2	0.2
18	63	9.2	8.9	9.2	9.1	0.2
19	63	9.3	8.9	9.1	9.1	0.2
20	63	9.1	8.9	8.8	9.0	0.2
21	63	9.1	8.9	8.9	9.0	0.1
23	63	9.3	9.0	9.0	9.1	0.1
0	51	12.1	12.1	12.1	12.1	0.0
1	51	10.5	10.4	10.8	10.5	0.2
6	51	8.7	8.4	8.4	8.5	0.2
9	51	8.2	8.0	8.1	8.1	0.1
12	51	7.9	7.8	7.8	7.8	0.0
16	51	7.7	7.9	7.8	7.8	0.1
18	51	7.9	7.9	7.9	7.9	0.0
20	51	7.9	7.9	7.9	7.9	0.0
24	51	7.8	7.8	8.1	7.9	0.1

Table A10. Moisture content of hemp seed stored at 35℃ in 0% dockage

Storage period (Weeks)	RH	Moisture content (%, Wb)			Mean	S.D.
		R1	R2	R3		
0	90	15.5	15.5	15.5	15.5	0.0
1	90	14.4	14.2	14.2	14.3	0.1
5	90	14.8	14.8	13.8	14.4	0.6
7	90	15.0	13.3	14.5	14.3	0.8
0	75	13.8	13.8	13.8	13.8	0.0
1	75	13.0	13.0	13.1	13.0	0.1
6	75	12.4	12.8	12.8	12.7	0.2
9	75	12.4	12.8	12.3	12.5	0.3
0	62	12.2	12.2	12.2	12.2	0.0
1	62	11.5	11.6	11.5	11.5	0.1
2	62	10.7	10.4	10.1	10.4	0.3
6	62	10.4	10.4	10.3	10.3	0.0
9	62	10.5	10.3	10.3	10.4	0.1
0	48	12.1	12.1	12.1	12.1	0.0
1	48	11.3	11.0	11.2	11.2	0.2
2	48	10.6	10.2	10.2	10.4	0.2
6	48	9.7	9.3	9.4	9.5	0.2
13	48	9.6	9.5	9.3	9.5	0.2

Table A11. Moisture content of hemp seed stored at 35℃ in 5% dockage

Storage period (Weeks)	RH	Moisture content (%, Wb)			Mean	S.D.
		R1	R2	R3		
0	90	15.5	15.5	15.5	15.5	0.0
1	90	14.5	13.6	13.5	13.9	0.6
6	90	14.4	14.2	14.2	14.2	0.1
7	90	15.2	12.8	14.5	14.2	1.2
8	90	13.3	13.8	14.5	13.9	0.6
0	75	13.8	13.8	13.8	13.8	0.0
3	75	12.3	12.6	12.7	12.5	0.2
6	75	12.5	12.5	12.2	12.4	0.1

7	75	12.6	12.4	12.4	12.4	0.1
8	75	12.6	12.2	12.5	12.4	0.2
10	75	12.5	12.3	12.3	12.4	0.1
0	62	12.2	12.2	12.2	12.2	0.0
1	62	11.6	11.4	11.7	11.6	0.2
4	62	10.7	10.4	9.9	10.3	0.4
6	62	10.3	10.0	10.1	10.2	0.1
10	62	10.6	10.2	10.3	10.4	0.2
11	62	10.4	10.2	10.3	10.3	0.1
0	48	12.1	12.1	12.1	12.1	0.0
1	48	11.3	11.1	11.4	11.3	0.2
6	48	10.5	10.3	10.3	10.4	0.1
8	48	10.3	9.8	10.0	10.0	0.2
12	48	10.0	9.5	9.6	9.7	0.3

Table A12. Moisture content of hemp seed stored at 35℃ in 15% dockage

Storage period (Weeks)	RH	Moisture content (%, Wb)			Mean	S.D.
		R1	R2	R3		
0	90	15.5	15.5	15.5	15.5	0.0
1	90	14.0	13.7	13.5	13.8	0.2
6	90	13.3	13.7	14.1	13.6	0.3
8	90	12.7	13.5	13.7	13.2	0.5
0	75	13.8	13.8	13.8	13.8	0.0
1	75	13.0	12.9	12.8	12.9	0.1
6	75	12.9	12.8	12.3	12.8	0.3
9	75	12.5	12.4	12.1	12.4	0.2
10	75	12.3	12.5	12.6	12.4	0.1
0	62	12.2	12.2	12.2	12.2	0.0
1	62	11.6	11.6	11.5	11.6	0.0
6	62	11.1	10.8	10.8	10.9	0.1
8	62	10.7	10.8	10.8	10.7	0.1
9	62	10.7	10.5	10.5	10.6	0.1
11	62	10.8	10.7	10.5	10.7	0.1
0	48	12.1	12.1	12.1	12.1	0.0
1	48	11.5	11.7	11.4	11.6	0.1
6	48	10.6	10.1	10.3	10.3	0.3
8	48	10.0	10.0	9.9	10.0	0.1
10	48	10.2	9.8	9.8	10.0	0.2
12	48	9.6	9.7	9.6	9.6	0.1

APPENDIX B: GERMINATION DATA

Table B1. Germination of hemp seed stored at 20℃ in 0% dockage

Storage period (Weeks)	RH	Germination (%)			Mean	S.D.
		R1	R2	R3		
2	94	56	76	68	66.7	10.1
4	94	64	52	64	60.0	6.9
8	94	64	40	48	50.7	12.2
10	94	56	52	32	46.7	12.9
13	94	40	36	40	38.7	2.3
16	94	24	40	32	32.0	8.0
3	75	96	96	96	96.0	0.0
12	75	72	68	64	68.0	4.0
14	75	68	76	52	65.3	12.2
16	75	68	72	56	65.3	8.3
18	75	56	72	48	58.7	12.2
26	75	36	48	36	40.0	6.9
4	65	88	88	88	88.0	0.0
12	65	92	92	80	88.0	6.9
14	65	84	84	92	86.7	4.6
18	65	64	84	88	78.7	12.9
26	65	72	88	72	77.3	9.2
4	54	100	84	96	93.3	8.3
12	54	100	96	88	94.7	6.1
14	54	84	84	96	88.0	6.9
18	54	80	88	88	85.3	4.6
26	54	88	96	80	88.0	8.0

Table B2. Germination of hemp seed stored at 20℃ in 5% dockage

Storage period (Weeks)	RH	Germination (%)			Mean	S.D.
		R1	R2	R3		
4	94	60	72	68	66.7	6.1

6	94	40	68	68	58.7	16.2
8	94	56	44	44	48.0	6.9
10	94	40	24	28	30.7	8.3
13	94	36	32	32	33.3	2.3
14	94	20	20	36	25.3	9.2
16	94	24	8	16	16.0	8.0
3	75	88	80	84	84.0	4.0
6	75	84	72	56	70.7	14.1
10	75	52	60	60	57.3	4.6
14	75	56	64	56	58.7	4.6
18	75	32	84	40	52.0	28.0
26	75	36	52	40	42.7	8.3
4	65	96	92	96	94.7	2.3
8	65	92	80	92	88.0	6.9
12	65	84	84	96	88.0	6.9
14	65	80	96	92	89.3	8.3
18	65	84	80	88	84.0	4.0
26	65	60	64	72	65.3	6.1
4	54	96	88	84	89.3	6.1
8	54	100	88	92	93.3	6.1
12	54	92	92	80	88.0	6.9
18	54	88	80	88	85.3	4.6
26	54	60	80	88	76.0	14.4

Table B3. Germination of hemp seed stored at 20°C in 15% dockage

Storage period (Weeks)	RH	Germination (%)			Mean	S.D.
		R1	R2	R3		
2	94	68	72	72	70.7	2.3
4	94	56	56	68	60.0	6.9
6	94	52	40	60	50.7	10.1
8	94	52	28	44	41.3	12.2
10	94	28	24	40	30.7	8.3
13	94	28	20	16	21.3	6.1
3	75	76	72	88	78.7	8.3
6	75	76	72	68	72.0	4.0
10	75	80	52	44	58.7	18.9
14	75	60	68	52	60.0	8.0
18	75	64	56	56	58.7	4.6
26	75	40	52	24	38.7	14.1
4	65	84	96	88	89.3	6.1
8	65	84	80	84	82.7	2.3
14	65	80	80	80	80.0	0.0
18	65	68	80	84	77.3	8.3
26	65	56	64	72	64.0	8.0
8	54	84	96	92	90.7	6.1
12	54	88	88	84	86.7	2.3
14	54	100	88	72	86.7	14.1
18	54	72	88	68	76.0	10.6

Table B4. Germination of hemp seed stored at 25°C in 0% dockage

Storage period (Weeks)	RH	Germination (%)			Mean	S.D.
		R1	R2	R3		
2	93	72	72	84	76.0	6.9
3	93	64	64	56	61.3	4.6
5	93	40	48	48	45.3	4.6
9	93	40	24	24	29.3	9.2
11	93	20	12	28	20.0	8.0
13	93	12	8	0	6.7	6.1
2	75	92	92	76	86.7	9.2
4	75	60	84	80	74.7	12.9
6	75	60	68	84	70.7	12.2
11	75	44	56	56	52.0	6.9
13	75	32	60	40	44.0	14.4

15	75	24	36	40	33.3	8.3
17	75	36	28	24	29.3	6.1
18	75	12	8	28	16.0	10.6
3	64	88	92	92	90.7	2.3
6	64	92	96	80	89.3	8.3
9	64	88	88	88	88.0	0.0
16	64	88	88	84	86.7	2.3
26	64	76	76	68	73.3	4.6
4	53	88	100	92	93.3	6.1
16	53	92	96	88	92.0	4.0
20	53	84	92	100	92.0	8.0
26	53	84	80	96	86.7	8.3

Table B5. Germination of hemp seed stored at 25℃ in 5% dockage

Storage period (Weeks)	RH	Germination (%)			Mean	S.D.
		R1	R2	R3		
2	93	84	72	84	80.0	6.9
3	93	56	72	56	61.3	9.2
5	93	52	48	60	53.3	6.1
8	93	44	48	60	50.7	8.3
9	93	28	32	44	34.7	8.3
11	93	36	24	40	33.3	8.3
13	93	4	12	20	12.0	8.0
2	75	76	60	84	73.3	12.2
4	75	68	76	72	72.0	4.0
8	75	64	72	72	69.3	4.6
11	75	56	60	60	58.7	2.3
15	75	28	24	32	28.0	4.0
18	75	12	12	28	17.3	9.2
3	64	80	88	80	82.7	4.6
6	64	80	88	76	81.3	6.1
9	64	88	88	72	82.7	9.2
12	64	84	76	84	81.3	4.6
26	64	64	72	80	72.0	8.0
4	53	96	88	96	93.3	4.6
8	53	80	84	88	84.0	4.0
14	53	92	88	72	84.0	10.6
16	53	92	84	72	82.7	10.1
26	53	84	64	88	78.7	12.9

Table B6. Germination of hemp seed stored at 25°C in 15% dockage

Storage period (Weeks)	RH	Germination (%)			Mean	S.D.
		R1	R2	R3		
2	93	44	56	64	54.7	10.1
3	93	56	56	36	49.3	11.6
5	93	48	40	44	44.0	4.0
6	93	40	24	40	34.7	9.2
8	93	20	28	28	25.3	4.6
9	93	24	28	20	24.0	4.0
11	93	28	24	24	25.3	2.3
13	93	8	8	0	5.3	4.6
2	75	76	64	72	70.7	6.1
4	75	76	80	68	74.7	6.1
8	75	60	64	64	62.7	2.3
11	75	36	36	52	41.3	9.2
13	75	24	12	40	25.3	14.1
17	75	16	12	16	14.7	2.3
18	75	16	12	8	12.0	4.0
9	64	84	80	84	82.7	2.3
12	64	80	64	72	72.0	8.0
14	64	80	64	68	70.7	8.3
20	64	76	60	76	70.7	9.2
26	64	64	72	72	69.3	4.6
4	53	88	84	96	89.3	6.1
8	53	96	64	80	80.0	16.0
12	53	76	72	92	80.0	10.6
14	53	76	84	84	81.3	4.6
20	53	76	88	88	84.0	6.9
26	53	64	56	92	70.7	18.9

Table B7. Germination of hemp seed stored at 30°C in 0% dockage

Storage period (Weeks)	RH	Germination (%)			Mean	S.D.
		R1	R2	R3		
2	92	76	64	72	70.7	6.1
3	92	44	44	48	45.3	2.3
5	92	40	36	20	32.0	10.6
7	92	16	12	16	14.7	2.3

2	75	84	64	80	76.0	10.6
4	75	72	72	40	61.3	18.5
8	75	28	20	36	28.0	8.0
10	75	28	16	12	18.7	8.3
11	75	12	16	16	14.7	2.3
2	63	88	76	88	84.0	6.9
4	63	80	84	80	81.3	2.3
6	63	84	80	76	80.0	4.0
10	63	68	60	84	70.7	12.2
12	63	76	68	64	69.3	6.1
26	63	32	60	32	41.3	16.2
3	51	96	80	88	88.0	8.0
6	51	84	92	88	88.0	4.0
14	51	80	96	80	85.3	9.2
20	51	84	80	96	86.7	8.3
26	51	60	80	80	73.3	11.6

Table B8. Germination of hemp seed stored at 30°C in 5% dockage

Storage period (Weeks)	RH	Germination (%)			Mean	S.D.
		R1	R2	R3		
2	92	52	48	64	54.7	8.3
3	92	36	48	48	44.0	6.9
5	92	36	48	28	37.3	10.1
7	92	8	8	4	6.7	2.3
2	75	72	56	72	66.7	9.2
4	75	32	52	24	36.0	14.4
6	75	48	28	32	36.0	10.6
8	75	36	28	32	32.0	4.0
11	75	24	8	20	17.3	8.3
4	63	80	84	92	85.3	6.1
8	63	80	88	88	85.3	4.6
10	63	76	72	68	72.0	4.0
13	63	84	64	72	73.3	10.1
15	63	68	80	72	73.3	6.1
17	63	60	76	84	73.3	12.2
26	63	28	32	48	36.0	10.6
3	51	84	92	92	89.3	4.6
6	51	88	76	88	84.0	6.9
14	51	92	88	80	86.7	6.1

20	51	76	76	84	78.7	4.6
26	51	72	72	68	70.7	2.3

Table B9. Germination of hemp seed stored at 30°C in 15% dockage

Storage period (Weeks)	RH	Germination (%)			Mean	S.D.
		R1	R2	R3		
1	92	36	28	52	38.7	12.2
3	92	36	20	36	30.7	9.2
5	92	16	20	28	21.3	6.1
7	92	20	16	8	14.7	6.1
1	75	52	60	56	56.0	4.0
2	75	32	64	68	54.7	19.7
6	75	28	28	28	28.0	0.0
8	75	16	32	36	28.0	10.6
10	75	12	4	24	13.3	10.1
11	75	8	8	20	12.0	6.9
2	63	76	68	76	73.3	4.6
6	63	80	92	52	74.7	20.5
8	63	52	68	92	70.7	20.1
12	63	68	88	52	69.3	18.0
13	63	60	76	72	69.3	8.3
17	63	72	64	68	68.0	4.0
26	63	24	32	16	24.0	8.0
6	51	88	96	84	89.3	6.1
14	51	92	84	88	88.0	4.0
20	51	84	64	68	72.0	10.6
26	51	52	76	72	66.7	12.9

Table B10. Germination of hemp seed stored at 35°C in 0% dockage

Storage period (Weeks)	RH	Germination (%)			Mean	S.D.
		R1	R2	R3		
2	90	52	52	56	53.3	2.3
3	90	16	28	28	24.0	6.9
5	90	0	0	0	0.0	0.0
1	75	68	88	76	77.3	10.1
2	75	76	68	56	66.7	10.1

3	75	24	36	40	33.3	8.3
5	75	0	4	4	2.7	2.3
7	75	4	4	8	5.3	2.3
2	62	80	60	88	76.0	14.4
4	62	64	72	76	70.7	6.1
6	62	40	36	48	41.3	6.1
8	62	20	32	44	32.0	12.0
9	62	20	4	40	21.3	18.0
2	48	80	84	88	84.0	4.0
4	48	80	68	76	74.7	6.1
6	48	36	56	60	50.7	12.9
8	48	36	40	44	40.0	4.0
10	48	16	28	12	18.7	8.3

Table B11. Germination of hemp seed stored at 35℃ in 5% dockage

Storage period (Weeks)	RH	Germination (%)			Mean	S.D.
		R1	R2	R3		
1	90	44	48	56	49.3	6.1
2	90	36	56	48	46.7	10.1
3	90	16	24	12	17.3	6.1
5	90	4	0	0	1.3	2.3
1	75	72	80	84	78.7	6.1
2	75	48	48	68	54.7	11.6
3	75	56	48	52	52.0	4.0
5	75	8	4	12	8.0	4.0
2	62	76	72	72	73.3	2.3
4	62	60	76	76	70.7	9.2
6	62	32	56	56	48.0	13.9
8	62	8	32	20	20.0	12.0
9	62	20	8	24	17.3	8.3
2	48	80	76	72	76.0	4.0
4	48	64	72	68	68.0	4.0
6	48	44	48	40	44.0	4.0
8	48	40	40	52	44.0	6.9
10	48	16	28	20	21.3	6.1
12	48	0	24	12	12.0	12.0

Table B12. Germination of hemp seed stored at 35℃ in 15% dockage

Storage period (Weeks)	RH	Germination (%)			Mean	S.D.
		R1	R2	R3		
1	90	64	52	40	52.0	12.0
2	90	60	44	60	54.7	9.2
3	90	28	28	28	28.0	0.0
5	90	0	0	0	0.0	0.0
1	75	76	68	56	66.7	10.1
2	75	60	48	56	54.7	6.1
3	75	36	32	36	34.7	2.3
5	75	12	12	8	10.7	2.3
7	75	16	8	12	12.0	4.0
2	62	64	80	64	69.3	9.2
4	62	64	60	52	58.7	6.1
6	62	48	48	56	50.7	4.6
8	62	20	12	12	14.7	4.6
9	62	12	4	8	8.0	4.0
2	48	80	84	88	84.0	4.0
4	48	68	56	60	61.3	6.1
6	48	16	32	24	24.0	8.0
10	48	12	28	16	18.7	8.3
12	48	8	20	16	14.7	6.1

APPENDIX C: INVISIBLE MOLD DATA

Table C1. Invisible mold of hemp seed stored at different temperatures and relative humilities

Temp	RH	*Aspergillus flavus*	*Aspergillus candidus*	*Aspergillus ochraceus*	*Aspergillus wentii*	*Penicillium*	*Rhizopus*
35	90	1, 49	1, 49	2, 51	3, 23	3, 23	
	75	2, 58	2, 58	2, 58	3, 40	3, 40	
	62	2, 72	4, 66	2, 72	Never	7, 25	
	48	2, 81	4, 68	2, 81	Never	8, 37	
30	92	1, 42	2, 57	2, 57	2, 57	3, 40	
	75	1, 49	2, 65	2, 65	2, 65	8, 29	11, 14
	63	12, 73	2, 78	8, 79	2, 78	8, 79	
	51	12, 90	3, 85	8, 71	3	Never	
25	93	2, 70	2, 70	2, 70	2, 70	5, 47	11, 26
	75	2, 76	2, 76	2, 76	2, 76	8, 60	15, 31
	64	12, 81	3, 84	Never	3, 84	12, 81	
	53	12, 80	4, 82	Never	14, 83	12, 80	
20	94	3, 64	2, 67	2, 67	3, 64	6, 56	13, 31
	75	3, 86	3, 86	3, 86	3, 86	6, 72	
	65	12, 87	4, 90	18, 80	Never	8, 84	
	54	12, 89	4, 89	18, 82	Never	8, 91	

APPENDIX D: FATTY ACID VALUE DATA

Table D1. Fatty acid value of hemp seed stored at 20℃ in 0% dockage

Storage period (Weeks)	RH	FAV (mg KOH/100g dry grain)			Mean	S.D.
		R1	R2	R3		
4	94	844.6	630.9	512.0	662.5	168.6
10	94	1583.9	1738.1	1425.0	1582.3	156.5
14	94	1588.1	1875.9	1698.9	1721.0	145.2
16	94	1872.4	1887.0	2078.1	1945.8	114.8

1	75	53.0	54.3	45.1	50.8	5.0
10	75	461.9	165.5	637.7	421.7	238.7
18	75	811.8	257.9	918.7	662.8	354.7
26	75	988.2	580.4	1058.2	875.6	258.1
4	65	54.2	74.7	56.9	61.9	11.1
12	65	86.8	83.8	53.4	74.7	18.4
18	65	118.8	109.5	92.2	106.8	13.5
26	65	110.9	105.9	98.1	105.0	6.5
4	54	58.0	49.7	55.1	54.3	4.2
12	54	87.6	54.6	75.3	72.5	16.7
18	54	76.0	76.6	72.2	74.9	2.4
26	54	99.3	83.4	89.5	90.7	8.1

Table D2. Fatty acid value of hemp seed stored at 20℃ in 5% dockage

Storage period (Weeks)	RH	FAV (mg KOH/100g dry grain)			Mean	S.D.
		R1	R2	R3		
4	94	899.5	948.6	978.9	942.3	40.1
10	94	1835.1	1866.6	1792.9	1831.5	37.0
16	94	1828.4	2246.5	2045.3	2040.0	209.1
1	75	96.0	69.2	78.5	81.2	13.6
10	75	456.0	312.1	608.4	458.8	148.2
18	75	842.4	392.4	1046.2	760.3	334.5
26	75	997.0	646.9	1154.8	932.9	259.9
4	65	119.0	113.1	77.9	103.3	22.2
12	65	194.3	160.5	125.3	160.0	34.5
18	65	185.8	213.6	129.4	176.3	42.9
26	65	168.5	190.6	126.9	162.0	32.4
4	54	108.6	65.5	88.5	87.5	21.6
12	54	110.8	101.0	95.1	102.3	7.9
18	54	113.9	132.6	114.5	120.3	10.6
26	54	127.9	113.3	96.5	112.6	15.7

Table D3. Fatty acid value of hemp seed stored at 20℃ in 15% dockage

Storage period (Weeks)	RH	FAV (mg KOH/100g dry grain)			Mean	S.D.
		R1	R2	R3		
4	94	1085.7	952.0	766.7	934.8	160.2
10	94	1843.2	2334.1	1814.9	1997.4	291.9

14	94	1871.2	1789.7	2139.9	1933.6	183.3
16	94	1893.5	1520.7	1599.8	1671.3	196.4
1	75	160.6	145.4	96.5	134.2	33.5
10	75	656.5	285.4	709.0	550.3	230.9
18	75	712.5	382.1	976.3	690.3	297.7
26	75	859.1	436.7	1096.0	797.3	334.0
4	65	241.3	262.0	116.7	206.7	78.6
12	65	276.7	365.7	152.0	264.8	107.4
18	65	200.9	306.7	160.2	222.6	75.6
26	65	341.0	465.8	163.3	323.4	152.0
4	54	125.7	123.4	154.7	134.6	17.5
12	54	180.4	187.0	210.4	192.6	15.8
18	54	249.5	233.4	268.5	250.5	17.6
26	54	307.3	276.3	227.6	270.4	40.2

Table D4. Fatty acid value of hemp seed stored at 25℃ in 0% dockage

Storage period (Weeks)	RH	FAV (mg KOH/100g dry grain)			Mean	S.D.
		R1	R2	R3		
2	93	124.8	174.6	143.1	147.5	25.2
3	93	669.9	446.0	372.6	496.1	154.9
6	93	1396.2	1434.8	1559.7	1463.5	85.5
9	93	1773.7	1841.2	2028.8	1881.2	132.2
11	93	2125.7	2172.6	1864.3	2054.2	166.1
13	93	1865.1	1904.8	1831.3	1867.0	36.8
4	75	303.2	237.8	82.1	207.7	113.6
8	75	934.1	552.9	348.2	611.8	297.4
13	75	1396.9	940.6	709.9	1015.8	349.6
18	75	1686.6	1232.3	926.2	1281.7	382.6
3	64	51.3	52.2	55.8	53.1	2.4
12	64	105.8	92.2	73.6	90.5	16.2
20	64	111.8	95.7	114.6	107.4	10.2
26	64	134.5	122.8	123.7	127.0	6.5
4	53	78.3	64.2	65.5	69.3	7.8
12	53	67.4	82.7	69.5	73.2	8.3
20	53	79.7	78.4	101.7	86.6	13.1
26	53	94.4	98.5	124.7	105.8	16.5

Table D5. Fatty acid value of hemp seed stored at 25℃ in 5% dockage

Storage period (Weeks)	RH	FAV (mg KOH/100g dry grain)			Mean	S.D.
		R1	R2	R3		
2	93	324.7	289.1	343.9	319.3	27.8
3	93	573.1	763.6	506.9	614.5	133.3
6	93	1268.3	1659.0	1635.1	1520.8	219.0
9	93	1696.7	1994.7	1540.7	1744.1	230.7
11	93	1869.2	1896.9	1880.8	1882.3	13.9
13	93	1745.2	2199.1	1784.8	1909.7	251.4
4	75	304.1	324.9	157.4	262.1	91.3
8	75	1021.5	680.6	433.1	711.8	295.4
13	75	1434.4	1246.7	861.3	1180.8	292.2
18	75	2100.0	1372.6	1053.3	1508.6	536.5
3	64	56.2	73.7	57.3	62.4	9.8
12	64	130.1	152.7	125.1	136.0	14.7
20	64	144.8	144.2	149.8	146.2	3.1
26	64	200.5	141.8	219.2	187.2	40.4
4	53	78.6	80.7	109.5	89.6	17.2
12	53	87.9	62.1	106.3	85.5	22.2
20	53	118.7	186.4	135.7	146.9	35.2
26	53	165.3	124.0	118.4	135.9	25.6

Table D6. Fatty acid value of hemp seed stored at 25℃ in 15% dockage

Storage period (Weeks)	RH	FAV (mg KOH/100g dry grain)			Mean	S.D.
		R1	R2	R3		
2	93	353.0	337.2	255.5	315.2	52.3
3	93	503.5	528.3	831.3	621.0	182.5
6	93	1583.7	1296.7	1679.5	1520.0	199.2
9	93	2046.2	1822.9	1849.7	1906.2	121.9
11	93	2141.2	1923.0	1707.9	1924.0	216.6
4	75	421.6	363.8	143.0	309.4	147.1
8	75	941.3	692.2	296.9	643.4	325.0
13	75	1407.0	1141.3	681.6	1076.6	367.0
18	75	1508.1	1305.8	794.8	1202.9	367.6
3	64	203.2	150.4	152.8	168.8	29.8
12	64	244.1	204.3	126.3	191.6	59.9
20	64	271.4	261.1	221.6	251.4	26.3

26	64	211.6	234.4	335.6	260.5	66.0
4	53	147.6	113.9	216.5	159.3	52.3
12	53	206.3	108.4	178.8	164.5	50.5
20	53	241.9	155.3	301.9	233.0	73.7
26	53	314.7	196.5	262.0	257.8	59.2

Table D7. Fatty acid value of hemp seed stored at 30°C in 0% dockage

Storage period (Weeks)	RH	FAV (mg KOH/100g dry grain)			Mean	S.D.
		R1	R2	R3		
3	92	1377.2	1278.9	1311.2	1322.4	50.1
5	92	1679.9	1938.1	1819.0	1812.3	129.2
7	92	1671.8	1695.6	2057.6	1808.3	216.2
9	92	1976.4	2268.4	2055.3	2100.0	151.0
2	75	184.8	202.1	303.2	230.1	63.9
6	75	1019.8	1265.2	1180.9	1155.3	124.7
8	75	1451.0	1350.0	1351.4	1384.1	57.9
11	75	1282.5	1667.3	1509.9	1486.6	193.5
2	63	43.1	68.0	48.1	53.1	13.2
12	63	69.0	90.3	91.4	83.5	12.6
17	63	86.2	100.9	87.3	91.5	8.2
26	63	123.2	127.9	104.2	118.5	12.6
3	51	39.3	65.1	46.5	50.3	13.3
12	51	58.3	66.8	75.3	66.8	8.5
20	51	90.2	97.3	93.7	93.7	3.6
26	51	103.6	127.7	101.8	111.0	14.5

Table D8. Fatty acid value of hemp seed stored at 30°C in 5% dockage

Storage period (Weeks)	RH	FAV (mg KOH/100g dry grain)			Mean	S.D.
		R1	R2	R3		
3	92	1109.1	1124.7	1104.7	1112.8	10.5
5	92	1429.5	1683.7	1682.3	1598.5	146.3
7	92	1463.3	1821.4	1702.4	1662.3	182.4
9	92	1772.9	1909.4	1901.6	1861.3	76.7
2	75	230.4	277.8	285.9	264.7	30.0
6	75	1130.9	1164.1	1054.4	1116.5	56.3
8	75	1285.0	1645.9	1651.1	1527.4	209.9

2	63	82.6	100.2	95.0	92.6	9.0
12	63	164.7	135.0	229.3	176.3	48.2
17	63	137.3	139.3	158.8	145.2	11.9
26	63	161.9	142.4	251.5	185.3	58.2
3	51	125.1	46.7	71.8	81.2	40.0
12	51	164.9	119.5	110.8	131.7	29.1
20	51	177.6	172.1	162.9	170.9	7.4
26	51	218.2	231.5	180.4	210.0	26.5

Table D9. Fatty acid value of hemp seed stored at 30℃ in 15% dockage

Storage period (Weeks)	RH	FAV (mg KOH/100g dry grain)			Mean	S.D.
		R1	R2	R3		
3	92	1266.0	965.7	1232.1	1154.6	164.5
5	92	1446.1	1387.2	1677.0	1503.4	153.2
7	92	1639.4	1502.0	1763.0	1634.8	130.6
9	92	1839.4	1809.2	2097.7	1915.5	158.6
2	75	386.4	379.7	388.4	384.8	4.5
6	75	1290.3	1184.4	1283.7	1252.8	59.4
8	75	1340.4	1540.5	1430.8	1437.3	100.2
11	75	1622.6	1931.2	1724.3	1759.4	157.2
2	63	126.6	82.6	117.8	109.0	23.3
12	63	208.7	196.2	179.6	194.8	14.6
17	63	222.1	278.4	175.8	225.5	51.4
26	63	295.8	331.0	310.2	312.4	17.7
3	51	115.5	138.3	129.5	127.8	11.5
12	51	194.2	178.2	168.0	180.1	13.2
20	51	359.3	313.0	226.2	299.5	67.5
26	51	238.1	275.7	214.1	242.6	31.1

Table D10. Fatty acid value of hemp seed stored at 35℃ in 0% dockage

Storage period (Weeks)	RH	FAV (mg KOH/100g dry grain)			Mean	S.D.
		R1	R2	R3		
3	90	1344.2	1538.0	1539.4	1473.8	112.3
5	90	2265.2	2047.4	2038.9	2117.2	128.3

7	90	2792.2	2609.8	2551.2	2651.1	125.7
2	75	405.9	342.0	497.2	415.1	78.0
5	75	1371.3	1369.9	1995.3	1578.9	360.7
8	75	1778.2	1851.2	1771.5	1800.3	44.2
4	62	83.8	62.6	69.4	71.9	10.9
6	62	164.2	81.6	71.8	105.8	50.7
8	62	159.4	81.1	99.7	113.4	40.9
10	62	261.3	120.8	106.1	162.7	85.7
4	48	60.7	83.5	52.3	65.5	16.1
6	48	71.6	86.0	102.6	86.7	15.5
8	48	77.0	68.6	97.9	81.2	15.1
12	48	85.5	81.4	100.4	89.1	10.0

Table D11. Fatty acid value of hemp seed stored at 35℃ in 5% dockage

Storage period (Weeks)	RH	FAV (mg KOH/100g dry grain)			Mean	S.D.
		R1	R2	R3		
3	90	1336.9	1341.9	1357.1	1345.3	10.5
5	90	1234.3	1864.1	1763.8	1620.7	338.4
7	90	2043.4	2420.7	2353.6	2272.6	201.3
2	75	385.3	352.3	312.5	350.0	36.5
5	75	1314.0	1462.3	1223.4	1333.3	120.6
8	75	1746.4	1621.3	1893.2	1753.6	136.1
4	62	109.6	148.7	70.3	109.5	39.2
6	62	150.5	191.7	137.6	159.9	28.3
8	62	196.9	150.0	100.6	149.2	48.1
10	62	272.1	187.3	129.5	196.3	71.7
4	48	55.8	107.6	94.9	86.1	27.0
6	48	82.1	135.4	156.8	124.8	38.4
8	48	91.8	125.9	127.1	114.9	20.0
12	48	114.6	138.0	147.2	133.3	16.9

Table D12. Fatty acid value of hemp seed stored at 35℃ in 15% dockage

Storage period (Weeks)	RH	FAV (mg KOH/100g dry grain)			Mean	S.D.
		R1	R2	R3		
3	90	1587.7	1410.9	1477.7	1492.1	89.3

5	90	1692.1	1350.7	2015.4	1686.1	332.4
7	90	2236.0	2278.2	2506.1	2340.1	145.3
2	75	557.2	542.0	351.4	483.5	114.7
5	75	1301.3	1126.8	1382.1	1270.1	130.5
8	75	1684.0	1515.8	1783.5	1661.1	135.3
4	62	130.9	223.9	188.8	181.2	47.0
6	62	226.1	198.6	229.0	217.9	16.8
8	62	224.7	194.4	155.9	191.7	34.5
10	62	171.8	221.7	194.4	196.0	25.0
4	48	151.5	102.6	76.8	110.3	37.9
6	48	187.5	124.0	112.6	141.4	40.4
8	48	151.0	111.6	129.7	130.8	19.7
12	48	180.2	140.3	112.7	144.4	34.0

APPENDIX E: SEED PLATE COUNT DATA

Procedure of seed plate count test was given below:

Materials/Equipment:

a. Petri film AC plates s/be stored at <8℃

b. Plastic spreading device provided with Petri film plates.

c. Appropriate Diluents

d. Stomacher or blender

e. Incubator - maintaining 32 to 35℃

f. p^H meter

g.1N NaOH

h. Colony counter/Magnified illuminator

Appropriate diluents:

-Butterfield's phosphate buffer

-IDF phosphate buffer (KH2PO4 at 0.0425 g/L pH 7.2)

-peptone salt diluent (ISO method 6887)

-buffered peptone water (ISO method 6579) 0.1% peptone water

-saline solution (0.85 to 0.9%),

-bisulfate-free letheen broth and

-distilled water

Inoculation and Incubation:

-Lift the top film and carefully inoculate 1 mL of sample or diluted sample to the center of bottom film. A pipette, pipettor or a plate loop continuous pipetting syringe can be used for sample addition.

-Drop top film onto sample.

-Distribute sample evenly using a downward pressure on the center of the plastic spreader, concave side down. Do not slide the spreader across the film. Leave plate undisturbed for at least 1 minute to permit the gel to solidify.

-Return unused plates to foil pouch. Seal pouch by folding and taping the open end. Store resealed foil pouch in a cool dry place. Use plates within one month after opening pouch. Exposure of Petrifilm plates to temperatures above 25 °C and/or humidities >50% RH can affect the performance of the plates.

-Incubate plates with the clear side up in stacks not exceeding 20 units. Follow current industry standards for incubation temperature. Incubate plates 48 ± 3 hours for bacteria determination.

Table E1. Seed Plate Count of hemp seed stored at 25℃ in 93% Relative humidity

Storage period (Weeks)	Dockage%	SPC (no. of colonies/g of samples)			SPC (Log_{10} value)			Mean	S.D.
		R1	R2	R3	R1	R2	R3		
1	0	270000	1960000	2140000	5.4	6.3	6.3	6.0	0.5
2	0	800000	800000	630000	5.9	5.9	5.8	5.9	0.1
3	0	110000	130000	160000	5.0	5.1	5.2	5.1	0.1
4	0	70000	50000	6360000	4.9	4.7	6.8	5.5	1.2

5	0	70000	40000	40000	4.9	4.6	4.6	4.7	0.1
6	0	10000	50000	110000	4.0	4.7	5.0	4.6	0.5
7	0	10000	70000	60000	4.0	4.9	4.8	4.5	0.5
8	0	80000	4400000	2800000	4.9	6.6	6.5	6.0	1.0
1	5	2460000	1440000	1600000	6.4	6.2	6.2	6.3	0.1
2	5	3140000	940000	790000	6.5	6.0	5.9	6.1	0.3
3	5	200000	570000	290000	5.3	5.8	5.5	5.5	0.2
4	5	230000	330000	270000	5.4	5.5	5.4	5.4	0.1
5	5	60000	400000	90000	4.8	5.6	5.0	5.1	0.4
6	5	60000	620000	110000	4.8	5.8	5.0	5.2	0.5
7	5	450000	130000	290000	5.7	5.1	5.5	5.4	0.3
8	5	90000	730000	580000	5.0	5.9	5.8	5.5	0.5
1	15	1400000	4200000	2540000	6.2	6.6	6.4	6.4	0.2
2	15	620000	320000	750000	5.8	5.5	5.9	5.7	0.2
3	15	580000	1820000	260000	5.8	6.3	5.4	5.8	0.4
4	15	150000	590000	400000	5.2	5.8	5.6	5.5	0.3
5	15	190000	390000	350000	5.3	5.6	5.5	5.5	0.2
6	15	180000	180000	480000	5.3	5.3	5.7	5.4	0.2
7	15	230000	210000	350000	5.4	5.3	5.5	5.4	0.1
8	15	220000	5410000	450000	5.3	6.7	5.7	5.9	0.7

Table E2. Seed Plate Count of hemp seed stored at 25℃ in 75% Relative humidity

Storage period (Weeks)	Dockage%	SPC (no. of colonies/g of samples)			SPC (Log_{10} value)			Mean	S.D.
		R1	R2	R3	R1	R2	R3		
1	0	1170000	2000000	2100000	6.1	6.3	6.3	6.2	0.1
2	0	1520000	1380000	470000	6.2	6.1	5.7	6.0	0.3
4	0	920000	630000	640000	6.0	5.8	5.8	5.9	0.1
6	0	570000	280000	220000	5.8	5.5	5.3	5.5	0.2
8	0	190000	90000	1600000	5.3	5.0	6.2	5.5	0.7
1	5	1480000	1800000	1860000	6.2	6.3	6.3	6.2	0.1
2	5	1420000	1500000	1000000	6.2	6.2	6.0	6.1	0.1
4	5	310000	2340000	650000	5.5	6.4	5.8	5.9	0.5
6	5	230000	370000	150000	5.4	5.6	5.2	5.4	0.2
8	5	130000	370000	140000	5.1	5.6	5.2	5.3	0.3
1	15	1700000	1800000	1040000	6.2	6.3	6.0	6.2	0.1
2	15	1430000	4600000	1500000	6.2	6.7	6.2	6.3	0.3
4	15	250000	660000	720000	5.4	5.8	5.9	5.7	0.3
6	15	260000	2140000	490000	5.4	6.3	5.7	5.8	0.5
8	15	190000	180000	350000	5.3	5.3	5.5	5.4	0.2

Table E3. Seed Plate Count of hemp seed stored at 25℃ in 64% Relative humidity

Storage period (Weeks)	Dockage%	SPC (no. of colonies/g of samples)			SPC (Log10 value)			Mean	S.D.
		R1	R2	R3	R1	R2	R3		
2	0	440000	760000	1600000	5.6	5.9	6.2	5.9	0.3
3	0	390000	480000	120000	5.6	5.7	5.1	5.5	0.3
6	0	510000	80000	120000	5.7	4.9	5.1	5.2	0.4
2	5	480000	360000	370000	5.7	5.6	5.6	5.6	0.1
3	5	400000	480000	510000	5.6	5.7	5.7	5.7	0.1
6	5	580000	170000	320000	5.8	5.2	5.5	5.5	0.3
2	15	680000	510000	470000	5.8	5.7	5.7	5.7	0.1
3	15	1320000	540000	2300000	6.1	5.7	6.4	6.1	0.3
6	15	800000	230000	150000	5.9	5.4	5.2	5.5	0.4

Table E4. Seed Plate Count of hemp seed stored at 25℃ in 53% Relative humidity

Storage period (Weeks)	Dockage%	SPC (no. of colonies/g of samples)			SPC (Log10 value)			Mean	S.D.
		R1	R2	R3	R1	R2	R3		
2	0	340000	700000	370000	5.5	5.9	5.6	5.7	0.2
4	0	310000	1070000	480000	5.5	6.0	5.7	5.7	0.3
8	0	340000	450000	240000	5.5	5.7	5.4	5.5	0.1
2	5	830000	680000	1150000	5.9	5.8	6.1	5.9	0.1
4	5		510000	740000	0.0	5.7	5.9	5.8	0.1
8	5	370000	550000	580000	5.6	5.7	5.8	5.7	0.1
2	15	2080000	3160000	3250000	6.3	6.5	6.5	6.4	0.1
4	15	1540000	1400000	1620000	6.2	6.2	6.2	6.2	0.0
8	15	1110000	1050000	440000	6.1	6.0	5.6	5.9	0.2

APPENDIX F: GREEN AND YELLOW SEED COUNT DATA

Table F1. Green and yellow seed count of hemp seed stored at 25℃ in 93% Relative humidity

Storage period (Weeks)	Dockage%	GYSC (%)			Mean	S.D.
		R1	R2	R3		
1	0	0	0	0	0.0	0.0
2	0	0.4	0	0	0.1	0.2
3	0	1.6	0.8	2	1.5	0.6
4	0	5.2	3.6	4.8	4.5	0.8
5	0	6	4.4	5.2	5.2	0.8
1	5	0.4	0	0.4	0.3	0.2
2	5	0.4	0	0.8	0.4	0.4
3	5	1.2	1.2	1.6	1.3	0.2
4	5	2.8	3.2	4	3.3	0.6
5	5	4	4	4.4	4.1	0.2
1	15	0.4	0	0	0.1	0.2
2	15	0	0	0.4	0.1	0.2
3	15	1.2	1.2	1.2	1.2	0.0
4	15	4.4	5.2	4.4	4.7	0.5
5	15	4.8	6	5.2	5.3	0.6

Table F2. Green and yellow seed count of hemp seed stored at 25℃ in 75% Relative humidity

Storage period (Weeks)	Dockage%	GYSC (%)			Mean	S.D.
		R1	R2	R3		
1	0	0.4	0.4	0	0.3	0.2
2	0	0.4	0.4	0	0.3	0.2
4	0	1.2	0.4	0	0.5	0.6
15	0	0	0.4	0.4	0.3	0.2
18	0	0.8	0.8	0	0.5	0.5
1	5	0.4	0	0	0.1	0.2
2	5	0.4	0	0.4	0.3	0.2
4	5	0.4	0	0.8	0.4	0.4
15	5	1.2	0	0	0.4	0.7
18	5	0.8	0	0	0.3	0.5
1	15	0	0	0.8	0.3	0.5

2	15	0	0	0	0.0	0.0
4	15	0.4	0.4	0.4	0.4	0.0
15	15	0.4	0	0	0.1	0.2
18	15	1.2	0	0	0.4	0.7

Table F3. Green and yellow seed count of hemp seed stored at 25℃ in 64% Relative humidity

Storage period (Weeks)	Dockage%	GYSC (%)			Mean	S.D.
		R1	R2	R3		
1	0	0	0.4	0	0.1	0.2
3	0	0	0.8	0	0.3	0.5
20	0	0	0	0	0.0	0.0
26	0	0	0	0	0.0	0.0
1	5	0	0.8	0.4	0.4	0.4
3	5	0.4	0	0.4	0.3	0.2
20	5	0	0	0	0.0	0.0
26	5	0	0	0	0.0	0.0
1	15	0	0	0.4	0.1	0.2
3	15	0	0.4	0.4	0.3	0.2
20	15	0.4	0	0	0.1	0.2
26	15	0	0	0	0.0	0.0

Table F4. Green and yellow seed count of hemp seed stored at 25℃ in 53% Relative humidity

Storage period (Weeks)	Dockage%	GYSC (%)			Mean	S.D.
		R1	R2	R3		
2	0	0.8	0.4	0	0.4	0.4
4	0	0	0	0	0.0	0.0
2	5	0.4	0	0	0.1	0.2
4	5	0	0	0.8	0.3	0.5
2	15	0.4	0	0	0.1	0.2
4	15	0.4	0	0	0.1	0.2